NORTHERN MPEP

Work Plan

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Submitted by:
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Sacramento Valley Water Quality Coalition
San Joaquin County and Delta Water Quality Coalition
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Table of Contents

List of Tables

List of Figures

Executive Summary

The Central Valley Regional Water Quality Control Board (Regional Water Board) requires that third-party groups conduct a Management Practices Evaluation Program (MPEP). The goal of the MPEP is to identify whether existing site-specific and/or commodity-specific agricultural management practices are protective of groundwater quality. Five Central Valley third-party groups formed the MPEP Group Coordination Committee (MPEP GCC) to jointly conduct MPEP studies in the Central Valley. The participating coalitions include the East San Joaquin Water Quality Coalition, Sacramento Valley Water Quality Coalition, San Joaquin County and Delta Water Quality Coalition, Westlands Water Quality Coalition, and the Westside San Joaquin River Watershed Coalition.

The MPEP organization includes the MPEP Group Coordination Committee (MPEP GCC), a Technical Advisory Committee, and an Administrative Coordinator. The MPEP GCC includes the Executive Directors of each Coalition, a grower/member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors. The role of the MPEP GCC is to approve study plans and modeling efforts, and allocate funds for the work. A Technical Advisory Committee (TAC) was formed to provide the expertise from multiple disciplines that the range of crops and studies is expected to demand. These technical experts are drawn from California Department of Food and Agriculture, University of California faculty, University of California Cooperative Extension, the International Plant Nutrition Institute, consulting companies, and commodity groups.

The goal of the MPEP program is to determine which management practices are protective of groundwater. The primary constituent of concern for the MPEP studies is nitrate although each of the northern MPEP GCC coalitions has additional Constituents of Concern. Specifically, the objectives of the MPEP stated in each of the Coalition's Waste Discharge Requirements are:

1) Identify whether site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability areas.
2) Determine if commonly implemented management practices are improving or may result in improving groundwater quality.
3) Develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern or equivalent method approved by the Executive Officer, must be provided.
4) Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

To address these four objectives, the MPEP will be implemented in three phases that overlap in time: Phase 1, develop information about management practices already demonstrated to help reduce nitrate discharges to groundwater in some agricultural settings (Objective 1); Phase 2, assessing the relative efficacy of management practices on groundwater quality using landscape-level modeling with the Surface Water Assessment Tool (SWAT) (Objective 3) and field studies; and Phase 3, assess the impacts of management practices on groundwater quality (Objectives 2 and 4).

During Phase 1, the MPEP GCC will develop an annotated list of studies and management practices that are identified as having the potential to reduce the amount of N leaching to groundwater. The list was completed in 2017.

The landscape model, Soil and Water Assessment Tool (SWAT), will be used during Phase 2 to estimate the amount of nitrogen leaching past the root zone. SWAT is a public domain model jointly developed by USDA and Texas A&M University. The model is used to simulate the quality and quantity of surface and groundwater. Phase 2 involves parameterizing SWAT for the entire Central Valley, calibrating and validating the model results, and refining the model. SWAT is being used by the Southern San Joaquin Valley (SSJV) MPEP group to evaluate the impact of management practices on groundwater quality in the Tulare Lake Basin. Using funds from a USDA Conservation Innovation Grant, the domain of the model is being expanded to the entire Central Valley region. The calibration and validation efforts will employ trusted data to adjust the model to improve its ability to represent cropping systems in the area (calibration), and then to check output against actual measurements for comparable situation (validation). Trusted data sources may include: 1) management and agronomic information from commercial fields, 2) similar raw data collected by CCAs and growers, and 3) field study and modeling results from literature. Additional modeling may be performed using Hydrus, a vadose zone physically-based model. For site-specific investigations, Hydrus can be used to evaluate the impact of management practices on leaching of N.

Phase 2 may involve some field studies and continue through the entire length of the MPEP process. Sensitivity analyses of SWAT (and Hydrus) model runs will guide the development of field studies by indicating which model parameter estimates should be improved to generate more accurate model results. Field studies will focus on developing better estimates of these critical model parameters. In Phase 3, SWAT will be used to evaluate the effect of a suite of management practices on the leaching of nitrate. Although initiated after early Phase 2 efforts, Phase 3 largely will be conducted at the same time as Phase 2. Once the model is calibrated appropriately, it can be used to evaluate the efficacy of management practices in limiting leaching of nitrate.

Introduction

The Central Valley Regional Water Quality Control Board's (CVRWQCB) Irrigated Lands Regulatory Program (ILRP) regulates the discharges from irrigated agriculture to surface and groundwater through the issuance of Waste Discharge Requirements (WDRs). To comply with the regulations in the WDRs, growers in the Central Valley joined Third Party groups that implement the required programmatic elements. One of the required elements is the implementation of the Management Practices Evaluation Program (MPEP). The goal of the MPEP is "to determine the effects, if any, irrigated agriculture practices have on first encountered groundwater under different conditions that could affect the discharge of waste from irrigated lands to groundwater (e.g., soil type, depth to groundwater, irrigation practice, crop type, nutrient management practice)." This goal leads to an evaluation of agricultural management practices to determine the degree to which they can reduce the leaching of constituents of concern, and in particular nitrate, to groundwater.

The WDRs allow Third Party groups to meet MPEP requirements by conducting evaluations on their own, or as a collective of Third Party Groups. The work plan provided here represents the framework for conducting the MPEP under the group option. The group consists of six of the Third Party groups in the Central Valley. The participants in this MPEP effort include: East San Joaquin Water Quality Coalition, Sacramento Valley Water Quality Coalition, San Joaquin County and Delta Water Quality Coalition, Westlands Water Quality Coalition, Grassland Drainage Area Coalition, and Westside San Joaquin River Watershed Coalition. Representatives from these coalitions formed the northern MPEP Groundwater Coordinating Committee (MPEP GCC) to perform the tasks necessary to reach the goal of the MPEP.

The objectives of the MPEP are to:

1. Identify whether site-specific and/or commodity specific management practices are protective of groundwater quality within high vulnerability groundwater areas,
2. Determine if newly implemented management practices are improving or may result in improving groundwater quality,
3. Develop an estimate of the effect of the Members' discharges of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern, or equivalent method approved by the Executive Officer, must be provided.
4. Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

To meet these objectives, the Third Party group(s) must develop "a scientifically sound approach for evaluating the effect of management practices on groundwater quality." This approach may include groundwater monitoring, surface, vadose zone and/or groundwater modeling, vadose zone sampling, or other methods that are approved by the Executive Officer. Over time, these tools will allow the northern MPEP GCC to identify practices that reduce leaching of nitrate past the root zone allowing members to be protective of groundwater quality. The northern MPEP GCC will identify the conditions under which protective practices can be implemented (e.g., soils, crops, irrigation methods). This knowledge can be transferred to members of the northern MPEP GCC Coalitions.

A Groundwater Monitoring Advisory Workgroup (GMAW) was formed which consisted of groundwater experts representing state agencies, the United States Environmental Protection Agency (USEPA), the United States Geological Survey (USGS), academia, and private consultants. The GMAW and Central Valley Water Board staff determined seven critical questions that should be answers with groundwater monitoring to comply with the ILRP. **Table 1** summarizes those questions and indicates whether the question is answered with the Groundwater Assessment Report (GAR), Groundwater Quality Trend Monitoring (GQTM), MPEP or Groundwater Quality Management Plan (GQMP). The MPEP is designed to answer Questions 2, 5, 6 and 7 and the 4 objectives of the MPEP.

TABLE 1. CRITICAL QUESTIONS TO BE ANSWERED WITH GROUNDWATER MONITORING CONDUCTED TO COMPLY WITH THE ILRP.

GMAW – ILRP Groundwater Critical Questions	Groundwater Assessment Report	Groundwater Quality Trend Monitoring	MPEP	Groundwater Quality Management Plan
1. What are irrigated agriculture's impacts to the beneficial uses of groundwater and where has groundwater been degraded or polluted by irrigated agricultural operations (horizontal and vertical extent)?	X	X		
2. Which irrigated agricultural management practices are protective of groundwater quality and to what extent is that determination affected by site conditions (e.g., depth to groundwater, soil type, and recharge)?		X	X	
3. To what extent can irrigated agriculture's impact on groundwater quality be differentiated from other potential sources of impact (e.g., nutrients from septic tanks or dairies)?	X	X		
4. What are the trends in groundwater quality beneath irrigated agricultural areas (getting better or worse) and how can we differentiate between ongoing impact, residual impact (vadose zone) or legacy contamination?	X	X		
5. What properties (soil type, depth to groundwater, infiltration/recharge rate, denitrification/ nitrification, fertilizer and pesticide application rates, preferential pathways through the vadose zone [including well seals, abandoned or standby wells], contaminant partitioning and mobility [solubility constants]) are the most important factors resulting in degradation of groundwater quality due to irrigated agricultural operations?			X	
6. What are the transport mechanisms by which irrigated agricultural operations impact deeper groundwater systems? At			X	

GMAW – ILRP Groundwater Critical Questions	Groundwater Assessment Report	Groundwater Quality Trend Monitoring	MPEP	Groundwater Quality Management Plan
what rate is this impact occurring and are there measures that can be taken to limit or prevent further degradation of deeper groundwater while we're identifying management practices that are protective of groundwater?				
7. How can we confirm that management practices implemented to improve groundwater quality are effective?			X	X

Meeting these objectives is expected to allow the Coalitions to answer several critical questions raised by the Groundwater Monitoring Advisory Group (GMAW):

- Which irrigated agricultural management practices are protective of groundwater quality and to what extent is that determination affected by site conditions (e.g., depth to groundwater, soil type, and recharge)? (Objective #1)
- What properties (soil type, depth to groundwater, infiltration/recharge rate, denitrification/nitrification, fertilizer and pesticide application rates, preferential pathways through the vadose zone [including well seals, abandoned or standby wells], contaminant partitioning and mobility [solubility constants]) are the most important factors resulting in degradation of groundwater quality due to irrigated agricultural operations? (Objective #3)
- What are the transport mechanisms by which irrigated agricultural operations impact deeper groundwater systems? At what rate is this impact occurring and are there measures that can be taken to limit or prevent further degradation of deeper groundwater while we're identifying management practices that are protective of groundwater? (Objective #3)
- How can we confirm that management practices implemented to improve groundwater are effective? (Objective #2)

Objective 4 requires using the information generated while addressing the first three objectives, combined with a review of each coalition member's farming practices to determine if any members may need to implement additional practices.

In addition to meeting direct requirements in the WDRs, the MPEP serves to assist members and Third Party groups in meeting other requirements contained in the Regional Water Board's Sacramento River and San Joaquin River Basins Water Quality Control Policy (referred to hereafter as Basin Plan). In particular, the Basin Plan incorporates statewide policies. Relevant here are the State Board's Statement of Policy with Respect to Maintaining High Quality of Waters in California, Resolution No. 68-16 (hereafter referred to as "Resolution 68-16" or "Antidegradation Policy"), and Policy for Nonpoint Source Pollution (Nonpoint Source Policy). With respect to the Antidegradation Policy, regional boards are required to maintain high quality waters (i.e., those waters that are better than water quality objectives) unless the Regional Water Board finds that the degradation is consistent with the maximum benefit to the people of the state, and the discharge is subject to waste discharge requirements that result in best practicable treatment or control (BPTC) of the discharge, and the highest water quality consistent with maximum benefit to the people of the state will be maintained. What constitutes BPTC is not defined in law, but the State Water Board has identified various factors for consideration of BPTC. Such factors include comparisons of existing methods, evaluation of performance data, and consideration of methods used by similarly situated dischargers. (See, e.g., Order R5-2012-0116-R2, Attachment A, p. 34.) Results of the MPEP will be instrumental in identifying and determining what constitutes BPTC for different crops in different areas of the Central Valley.

Upon completion of the MPEP, and submission of the Management Practices Evaluation Report, a Third Party group is required to update and/or amend its Groundwater Quality Management Plan (GQMP) to incorporate the findings from the MPEP. In other words, as management practices are found to be effective (or not) in minimizing the leaching of constituents of concern (i.e., nitrate) to groundwater, the GQMP should be revised to assist members in identifying appropriate management practices for implementation on their farming operation. Member implementation of management practices will assist members in meeting applicable groundwater receiving limits (and by extension the conditions outlined in the WDRs). If the MPEP demonstrates that management practices currently in use are not effective in protecting groundwater quality, the Third Party group in conjunction with other experts and entities shall propose new/alternative management practices for grower implementation.

Where high-quality waters do not exist, the State Water Board has indicated that permit limitations should be more stringent than Basin Plan objectives if such limitations can be met using best efforts, which are limitations expected to be achieved using reasonable control efforts. As with determining BPTC, the MPEP will be instrumental in identifying what is considered best efforts, or reasonable control methods, where there are not high-quality waters.

The Nonpoint Source Policy identifies five key elements for programs that are designed to control nonpoint source pollution, which includes discharges from irrigated agriculture. The MPEP, in conjunction with the GQMP and other monitoring and reporting requirements in the Waste Discharge Requirements, ensures compliance with at least two of the five key elements. The two most applicable key elements are the need to describe practices to be implemented and processes being used to select and verify proper implementation of practices (key element #2), and the need for feedback mechanisms to determine if the program is achieving its purpose (key element #4). Notably, the Sacramento County Superior Court recently evaluated the Central Coast Conditional Waiver, and found that it was not consistent with the Nonpoint Source Policy largely because the Court did not believe that there was a requirement/process within the program that verified if "implemented management practices were effectively controlling the relevant discharge." Unlike the Central Coast Conditional Waiver, the General Order includes the MPEP, which fulfills this need. The Management Practices Evaluation Report that must be submitted upon completion of the MPEP identify what management practices are protective of groundwater quality for a range of conditions.

In summary, the MPEP serves multiple purposes within the framework of the Orders. This work plan sets forth how the MPEP will be conducted and address the four objectives of the MPEP. In general, the work plan involves three phases:

- Phase 1 – Inventory effective management practices;
- Phase 2 – Landscape-level modeling using SWAT including calibration and validation;
- Phase 3 – Assessment of the impact of management practices on groundwater quality.

Moreover, the results of the work performed through the MPEP are expected to inform each individual Coalition's GQMP. With the GQMP's focus on grower performance measures involving Nitrogen Applied (A) and Nitrogen Removed (R) at harvest (or sequestered in permanent tissue) such as A/R and A – R, the MPEP will provide complimentary information on leaching rate. The information generated by the MPEP will allow an understanding of whether A/R or A – R are reasonable metrics to assess grower performance.

Nitrate in groundwater is of particular concern for agricultural operations because the act of farming necessarily requires nutrients in the soil to be replenished. Nitrogen (N) is added to the soil to stimulate the growth of agricultural crops, and nitrogen in organic and synthetic fertilizers can transform to nitrate and leach to groundwater. The presence of nitrates in groundwater at levels that meet or exceed the drinking water standard of 10 mg/L as N can have adverse impacts on public health if that groundwater is used for domestic and municipal drinking water purposes. As a result, it is the primary constituent of concern for all Third Party Groups in the northern MPEP GCC.

MPEP Background

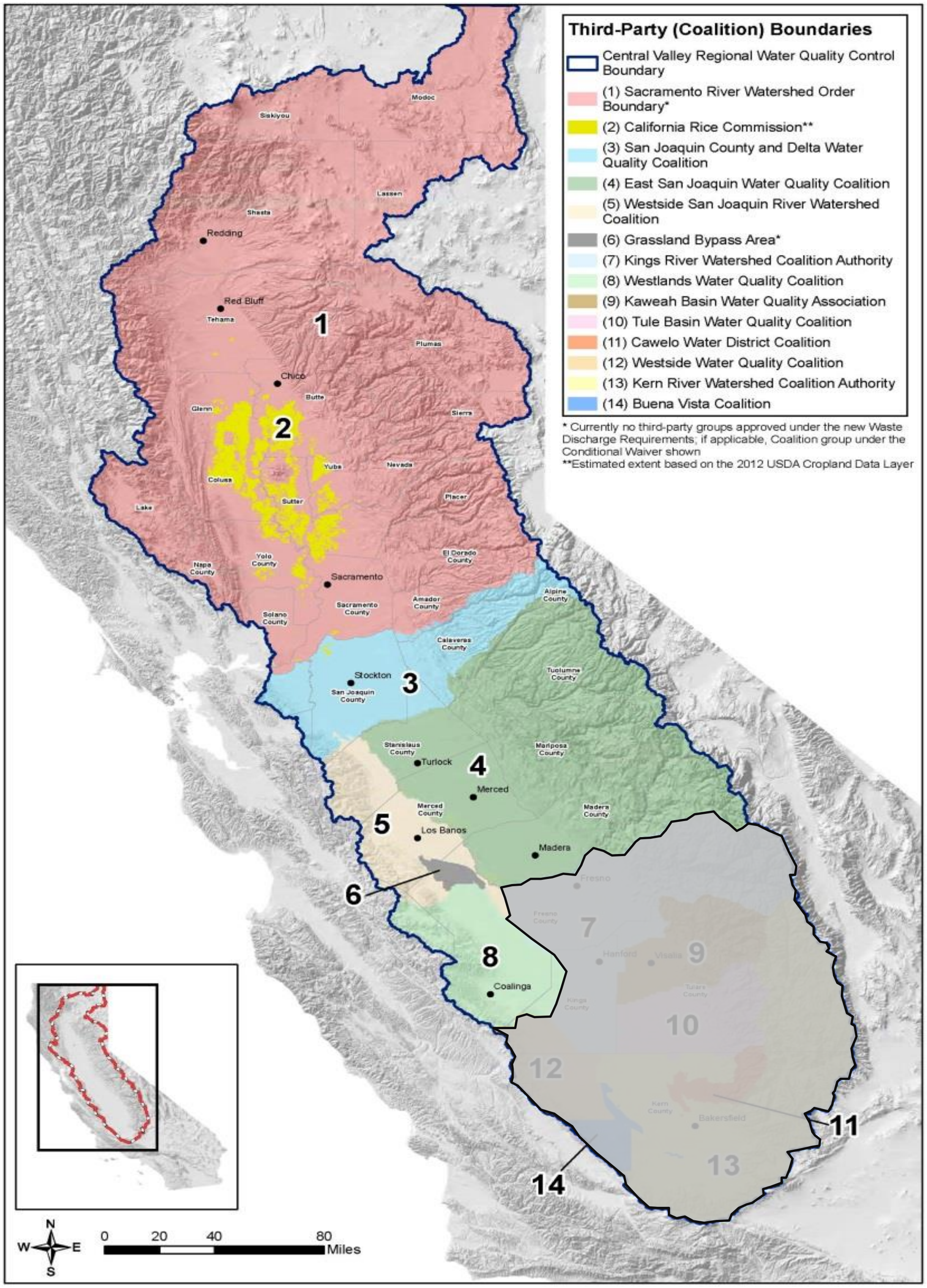
The Central Valley Regional Water Quality Control Board (Regional Water Board) requires that Third Party Groups develop and implement a Management Practices Evaluation Program (MPEP). The initial step in the MPEP is to develop a work plan that describes the tools and/or methods to be used to associate management practice activities on the land surface with the effect of those activities on underlying groundwater quality. This document is the work plan that provides the framework for all of the elements that will be developed as part of this program.

The MPEP is envisioned as the vehicle for developing the critical information on the effectiveness of groundwater management practices. As management practices are identified as reducing or eliminating the potential for leaching nitrate to groundwater, Coalition members in areas with similar characteristics, crops and conditions will be educated about the practices, and members will be required to implement practices that are protective of groundwater. Additionally, Groundwater Quality Trend Monitoring Programs (GTMP) implemented in each coalition region, and across a wider geographic scale through the Central Valley Groundwater Monitoring Collaborative (CVGMC) will evaluate potential changes in regional groundwater conditions.

Six Central Valley third-party groups formed an organization, the northern MPEP Group Coordination Committee (MPEP GCC) to develop the information necessary to satisfy MPEP requirements in the northern Central Valley. The participating coalitions include (**Figure 1**):

- East San Joaquin Water Quality Coalition,
- Sacramento Valley Water Quality Coalition,
- San Joaquin County and Delta Water Quality Coalition,
- Westlands Water Quality Coalition,
- Grassland Drainage Area Coalition, and
- Westside San Joaquin River Watershed Coalition.

FIGURE 1. ILRP COALITIONS IN THE CENTRAL VALLEY. THE CALIFORNIA RICE COMMISSION (NUMBER 2 IN THE MAP) IS NOT A MEMBER OF THE MPEP GCC. THE GRASSLANDS COALITION (NUMBER 6 IN THE MAP) IS ALSO NOT A MEMBER BUT IS PARTICIPATING AS PART OF THE WESTSIDE SAN JOAQUIN RIVER WATER QUALITY COALITION.



A letter was sent to the Regional Water Board on September 23, 2014 describing the northern MPEP GCC organization, members, participating individuals, and memorandum of agreement (Westlands Water Quality Coalition, Sacramento Valley Water Quality Coalition, and the Grassland Drainage Area Coalition were added to the MPEP GCC after the letter was submitted). A letter of approval for the approach was received on June 25, 2015.

The northern MPEP GCC submitted a work plan to the Regional Water Board on June 4, 2016 followed by a resubmittal on July 29, 2016. Since the July 29, 2016 submittal, the seven Tulare Basin ILRP Water Quality Coalitions joined together to develop and implement the Southern San Joaquin Valley MPEP (SSJV MPEP) effort. Those coalitions developed a MPEP Work Plan with some elements similar to the northern MPEP GCC work plan. In late 2016, the northern MPEP GCC determined that coordination with the south MPEP group was desirable. The northern MPEP GCC entered into discussions with the SSJV MPEP Committee and the Regional Water Board to better coordinate the two MPEP programs. Although the two MPEP groups will maintain their autonomy, timing of the MPEP GCC effort will now be aligned with the SSJV MPEP effort (see below) in that the initial technical approach will involve landscape modeling with SWAT.

An amended MPEP Work Plan was submitted on May 18, 2017, prior to the SSJV MPEP submitted their final Work Plan. Based on the ongoing collaboration with the SSJV MPEP and the MPEP GCC, it was decided to submit a Revised MPEP GCC Work Plan to better align timelines, phases and deliverables between the two efforts. This Revised MPEP GCC Work Plan describes the updated approach to better align and coordinate with the SSJV MPEP efforts. The most significant change includes an update to the overall approach to focus on modeling of irrigated land's root zones at both the field level and the landscape-level, including the effect of management practices on nitrate leaching. This approach will allow for better coordination between the two MPEP programs, and increase the ability to build upon shared resources across the Central Valley.

Coalition MPEP Process – Administration and Technical

Coordination with the SSJV MPEP involves expanding and implementing the SWAT model for the entire Central Valley. The initial expansion of the SWAT domain is being developed as part of the activities funded by a Natural Resources Conservation Service's Conservation Innovation Grant (CIG) awarded to the Kings River Watershed Coalition Authority. CIG activities will be ongoing throughout the length of the north-south coordinated effort as outlined in the SSJV MPEP Work Plan. The coordination will include model calibration and validation as well as refining the SWAT model during future years.

The administration of the northern MPEP GCC remains as described previously. The northern MPEP organization includes the MPEP GCC, a Technical Advisory Committee, and an Administrative Coordinator. The coalitions comprising the MPEP GCC will be responsible for providing the SSJV MPEP Committee with the information necessary to adequately expand the domain of the SWAT model, and parameterize the model for the northern MPEP GCC region. The role of each entity is described below.

MPEP Group Coordination Committee

The MPEP GCC is made up of representatives from six Central Valley water quality coalitions. These coalitions cover more than 5 million acres of irrigated cropland. On May 1, 2014, a Memorandum of Agreement (MOA) was established among the East San Joaquin River Watershed Coalition (ESJWQC), the San Joaquin County Resources Conservation District on behalf of the San Joaquin County and Delta Water Quality Coalition (SJCDWQC), and the San Joaquin Valley Drainage Authority on behalf of the Westside San Joaquin River Watershed Coalition (WSJRWC). The MOA provides supplemental information to the Coordination Agreement for the Management Practices Evaluation Group Option (effective 5/1/2014) and additional detail about the operation of the MPEP GCC. The MOA was later signed by the Sacramento Valley Water Quality Coalition (SVWQC), the Westlands Water Quality Coalition (WWQC), and the Grassland Drainage Area Coalition (GDAC). The role of the MPEP GCC is to direct the development, preparation, and implementation of the northern MPEP Group Work Plan and reporting.

The MPEP GCC includes the Executive Directors of each Coalition, a grower/member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors (**Table 2**). Parry Klassen (ESJWQC) serves as Chair and Joe McGahan (WSJRWC) is the Vice Chair.

Table 2. MPEP GCC members. The Chair and Vice Chair are also voting members of the MPEP GCC.

Name	Coalition	MPEP GCC Responsibility
Parry Klassen	ESJWQC	Chair MPEP GCC, Voting Member
Bill Brush	ESJWQC	Voting Member
Alan Reynolds	ESJWQC	Alternate
Michael Wackman	SJCDWQC	Voting Member
John Herrick	SJCDWQC	Voting Member
Diego Olagaray	SJCDWQC	Alternate
Joe McGahan	WSJRWC	Vice Chair MPEP GCC, Alternate
Dan Roberts	WSJRWC	Voting Member
David Cory	WSJRWC	Alternate
Bruce Houdesheldt	SVWQC	Voting Member
Lester Messina	SVWQC	Voting Member

Name	Coalition	MPEP GCC Responsibility
Kelly Huff	SVWQC	Alternate
Charlotte Gallock	WWQC	Voting Member
Russ Freeman	WWQC	Voting Member
Jose Gutierrez	WWQC	Alternate
David Cory	GDAC	Voting Member
Joe McGahan	GDAC	Alternate

The MPEP GCC will allocate funds for various technical activities that occur during the life of the MPEP. The MPEP GCC has contracted with the Coalition for Urban Rural Environmental Stewardship (CURES) to be the Administrative Coordinator to manage the projects and guarantee that work is progressing in a timely manner, and any contractors remain within budget.

Technical Advisory Committee

A Technical Advisory Committee (TAC) was formed to provide expertise to the northern MPEP GCC from experts in multiple disciplines that the range of crops and studies is expected to demand. The TAC has met with the MPEP GCC multiple times to receive input on the development of the Work Plan. These technical experts are drawn from California Department of Food and Agriculture, University of California faculty, University of California Cooperative Extension, the International Plant Nutrition Institute, consulting companies, and commodity groups.

The TAC is made up of the following individuals:

- Dr. Patrick Brown, UC Davis Department of Plant Sciences
- Dan Munk, UCCE Farm Advisor
- Allan Fulton, UCCE Irrigation and Water Resources Advisor
- Dr. Doug Parker, Director, California Institute for Water Resources, UC Division of Agriculture and Natural Resources
- Dr. Rob Mikkelsen, International Plant Nutrition Institute
- Dr. Tim Hartz, UCCE Vegetable Crops Specialist, Department of Vegetable Crops
- Dr. Lowell Zelinski, Precision Ag Consulting
- Dr. Gabriele Ludwig, Almond Board of California
- Mark Cady, CA Department of Food and Agriculture
- Vicki Kretsinger Grabert, Luhdorff and Scalmanini Consulting Engineers

Administrative Coordinator

The MPEP GCC has contracted with the Coalition for Urban Rural Environmental Stewardship (CURES) to serve as MPEP Administrative Coordinator. CURES performs the administrative functions for the program such as developing and managing funding, creating Scope of Work documents, working with contractors to develop budgets and contracts, tracking progress, and paying invoices.

Coordination with SSJV MPEP Group and Regional Water Board Review

The northern MPEP GCC and the SSJV MPEP Committee signed a Memorandum of Understanding (MOU) that remains in effect through December 2018. This document establishes the commitments of each group to the coordinated efforts, and allows each group to have technical representation at meetings by the other group. The MPEP GCC and SSJV MPEP Committee jointly will work with Regional

Water Board staff to ensure that the work performed as part of the MPEP complies with the MPEP requirements included in the ILRP WDRs.

The SSJV MPEP group is expanding the domain of the SWAT model to the entire Central Valley. The results of the modeling efforts will be provided to the northern MPEP GCC as they are delivered to the USDA allowing the northern MPEP GCC to initiate its modeling efforts immediately.

The coordinated effort requires revision of deadlines for submission of the Management Practice Evaluation Report (MPER) by the northern MPEP GCC coalitions. The WDRs require the submission of the MPER within six years of the initiation of the MPEP. The northern MPEP GCC MOA was signed in 2014 and activities have been initiated through the MPEP GCC even though a Work Plan has not yet been approved. Coordination with the SSJV MPEP will likely delay the submission of the northern MPEP GCC MPER until 2024 (6 years from the submission of this Work Plan). However, the MPEP GCC will provide annual updates on the MPEP to the participating coalitions for incorporation into their annual reports.

The northern MPEP GCC will follow the schedule of activities provided in the SSJV MPEP Work Plan (Figures 3-1A and 3-1B in the SSJV MPEP Work Plan). On the time schedule established in the SSJV MPEP Work Plan, the MPEP GCC will submit a MPER in 2024, describing management practices that are protective of groundwater quality for the range of conditions found at farms located in the Sacramento and San Joaquin River Basins. Information from the report will be used by the Regional Water Board staff and third-party members to identify the types of management practices that should be implemented in certain areas based on site-specific conditions.

Timeline

The timeline for the MPEP GCC follows the schedule for the SSJV MPEP. The timeline for the SSJV MPEP is to extend the domain of the SWAT model to the Sacramento River and San Joaquin River basins during the first year of their program. It is anticipated that for the first year, progress will include the SWAT baseline model and initial management practice model runs. In subsequent years, the SWAT model will be refined and additional management practices imposed on the landscape.

MPEP - Constituents of Concern (COC)

Pesticides

Pesticides are COCs in some of the Coalition regions. Currently the California Department of Pesticide Regulation (CCDPR) monitors groundwater for pesticides across the state through their Groundwater Protection Program (GPP). CDPR has an extremely thorough GPP that involves identifying potential pesticide contaminants, monitoring for pesticides, and performing a formal review of all pesticides and pesticide degradates detected.

When pesticides are registered for use, the product registrant must submit extensive chemical and environmental fate data. CDPR uses these data to determine if the product is sufficiently persistent and mobile that it could be moved to groundwater. Products meeting these two criteria are added to the State's Groundwater Protection List. Once on the list, CDPR samples groundwater for these products when use reports indicates that they were used in the vicinity of the wells sampled.

Samples are collected and analyzed for pesticides on the Groundwater Protection List. If any pesticides are detected and the results confirmed, CDPR determines if the contamination is the result of legal use by agriculture. If contamination by legal use is confirmed, CDPR moves to the Pesticide Contamination Prevention Act review process. This process involves issuing a formal notice of detection to the product's registrant(s). If the registrant does not respond to the notice by requesting a public hearing, the product's registration is cancelled. If a hearing is requested, it is held before the Pesticide Registration and Evaluation Committee where written and oral comments are accepted. The Committee then meets a second time where staff from CDPR, OEHHA, and the SWRCB may provide additional information. The Committee then deliberates and provides its findings to the Director of CDPR. The Committee can determine 1) the ingredient found in the soil or groundwater has not polluted, and does not threaten to pollute the groundwater of the state, 2) the ingredient found in the soil or groundwater can be modified so that there is a high probability that the pesticide would not pollute the groundwater of the state, or 3) the modification of the product pursuant to (2) above, or the cancellation of the registration will cause severe economic hardship on the state's agricultural industry. The Director of CDPR, within 30 days of the Subcommittee's report can make any of the following decisions, 1) concurs with the Subcommittee's findings that the pesticide does not or will not cause pollution of groundwater, 2) concurs with the Subcommittee that modifications of the pesticide are required to prevent pollution, 3) concurs with the Subcommittee's finding that the loss of the pesticide will cause severe economic hardship to the state's agricultural industry, or 4) determines that, contrary to the findings of the Subcommittee, the pesticide does not pollute or cause a threat to pollute and no modifications are necessary.

In addition, CDPR can designate Groundwater Protection Areas (GPAs) which are areas with either known contamination by pesticides, or have soil conditions and depth to groundwater shallower than 70 feet that make the groundwater vulnerable to contamination. Applications of pesticides in these areas require notification of County Agricultural Commissioners and the use of protective management practices to prevent the leaching of chemicals to groundwater. CDPR is continually reviewing groundwater monitoring data from the GPP and from other agencies (e.g., the State Board's Division of Drinking Water program) to determine if additional Groundwater Protection Areas should be designated.

The ILRP Coalitions rely on the process of pesticide review, monitoring, and evaluation of product registration as the primary management strategy approach for pesticides detected in groundwater.

Salt

Although not a problem across the entire northern MPEP GCC region, salt is problematic across a large amount of the Central Valley including several of the northern MPEP coalitions. Unlike pesticides registered for use only by agriculture, there are a large number of dischargers of salt including Publicly Owned Treatment Works (POTWs) and food processors. Currently the Central Valley Salinity Alternatives for Long Term Sustainability (CV SALTS) brings together dischargers of salt (irrigated agriculture, ranchers, municipalities, food processors) from across the region, and federal, state, and local agencies, and environmental justice groups with the goal of achieving a balance between maintaining a strong economy while ensuring safe drinking water. The approach developed through the CV SALTS process includes short-term solutions and a long-term approach to salt management. Short-term solutions include:

- Continued implementation of existing pollution prevention, watershed, and salt reduction plans,
- Continued maintenance of current salinity discharge levels,
- Enforced compliance with Interim Permit Limits,
- Implementation of new salinity management practices and source control activities,
- Monitoring of salinity discharge activities where required, and
- Participating in the Prioritization and Optimization Study.

Long-term solutions will be accomplished using a phased approach. The phases are:

1. Development – perform the Prioritization and Optimization Study that will define potential regional and subregional approaches, identify funding sources, and establish governance structures to implement large-scale projects,
2. Funding – obtain funding and complete environmental permitting and engineering/design for projects identified in Phase 1, and
3. Construct Projects – construct the salt management projects developed in Phases 1 and 2.

The Central Valley Water Board began the release of the draft Basin Plan Amendment to reflect work to date. Adoption of the Basin Plan Amendment by the Central Valley Water Board is scheduled for some time between April and July 2018. After review and approval by the State Board's Office of Administrative Law, groundwater actions are expected to be implemented in high priority areas by the end of 2018.

The CV SALTS process is a collaborative effort that involves potentially the development of large and expensive projects such as construction and operation of regional desalters, discharge brine lines, or reprocessing facilities. Other more localized management measures include the recycling and reuse of irrigation water resulting in the concentration of salt, or the implementation of a real-time management program that can export salt by using the assimilative capacity of the major drainages in the Sacramento and San Joaquin Valleys. All of the northern MPEP coalitions are participating in the CV SALTS process and all are expected to be active in the development and funding of the projects identified in the Phase 1 Prioritization and Optimization Study. These projects are expected to be accompanied by the development of site-specific management practices that can be implemented by all dischargers, including the growers regulated by the ILRP. Because of this parallel process to manage salt, the northern MPEP GCC will not make salt management a focus of the MPEP. Instead, due to the rapidly approaching adoption of the Basin Plan Amendment for salt, the northern MPEP GCC Coalitions will evaluate and implement management practices for salt through that program. Updates on progress will be included in the MPEP Annual Update (see below).

Nitrate

Nitrate is the focal COC for the northern MPEP. It is the single constituent listed by all six Coalitions in their Groundwater Assessment Reports (GARs) as a COC. It's presence in groundwater has been attributed to the use of fertilizers by irrigated agriculture although there are additional sources such as fertilizers applied in urban areas. All GARs used the presence of nitrate in groundwater as a factor in designating their High Vulnerability Areas which require reporting of nitrogen applied and nitrogen removed. Almost all growers apply some sort of nitrogen to their crops, leading to the potential for widespread leaching but also leading to the potential for implementation of management practices that can reduce leaching of nitrate to groundwater. Because of the widespread contamination and concentrations in drinking water that far exceed the primary maximum contaminant level (MCL), identifying management practices that can reduce leaching is critically important.

Some practices are generally understood as being useful in reducing the movement of nitrate to groundwater, e.g., installing backflow prevention devices on wells that are used for fertigation. The effectiveness of other practices, e.g., split applications, are generally understood to be effective but there is uncertainty about the number of applications that should be used and/or the timing of applications on different soil types or with different irrigation practices. This uncertainty prevents the development of a single set of recommendations that can be used reliably across the northern MPEP GCC region to achieve the balance between maintaining adequate yields and eliminating leaching of nitrate to groundwater.

MPEP - Deliverables

MPEP Annual Update

Each year, the MPEP GCC will provide an Annual Update to the member organizations. This update will outline progress to date and the planned activities for the upcoming year. Specific information in the MPEP Annual Update will likely include:

- Summary of activities conducted under the MPEP
- Summary of coordination actions between the SSJV MPEP and the MPEP GCC
- Update on MPEP activities, as appropriate, such as: SWAT model development, model calibration and validation, and assessment of management practices.

An update on MPEP progress will be provided to each MPEP Coalition in time to allow them to insert the report in their own Annual Report by reference or in its entirety.

Landscape-level modeling (Phase 2) will be an iterative, evolving process. A greater understanding of critical rates and nutrient pools will be generated during the modeling that occurs every year. As each year's modeling results are generated and evaluated, it is expected that the model's representation of irrigated lands will improve, as the MPEP groups better understand how to represent crops, soils, and practices. Landscape-level modeling results will help coalitions to prioritize specific regions within the northern MPEP HVA areas for outreach about specific practices and specific crops. Pertinent information about practices, performance, and practice adoption will be included in coalition annual updates.

MPEP GCC Final Report – Management Practices Evaluation Report (MPER)

After the first six years of the MPEP, the northern MPEP GCC will provide an evaluation of the knowledge gained and determine the next steps that need to be accomplished to meet the objectives of the MPEP. Included in the Management Practice Evaluation Report will be:

- List of management practices evaluated in the MPEP that are considered to be protective of groundwater.
- Evaluation of the conditions under which each management practice evaluated by the MPEP GCC is considered protective of groundwater.
- Discussion of where in the MPEP GCC Coalition region each of the management practices should be recommended to growers.
- Technical justification for results and conclusions.

MPEP – Conceptual Approach

As outlined in the Orders of the MPEP GCC coalitions, the general objective of the MPEP program is to identify management practices that are protective of groundwater (e.g., Order R5-2012-0116-R2, Attachment B, Section IV.B). The focus of the MPEP are practices that are implemented, or that could be implemented in High Vulnerability Areas (HVAs) within each Coalition region.

Specifically, the objectives of the MPEP are:

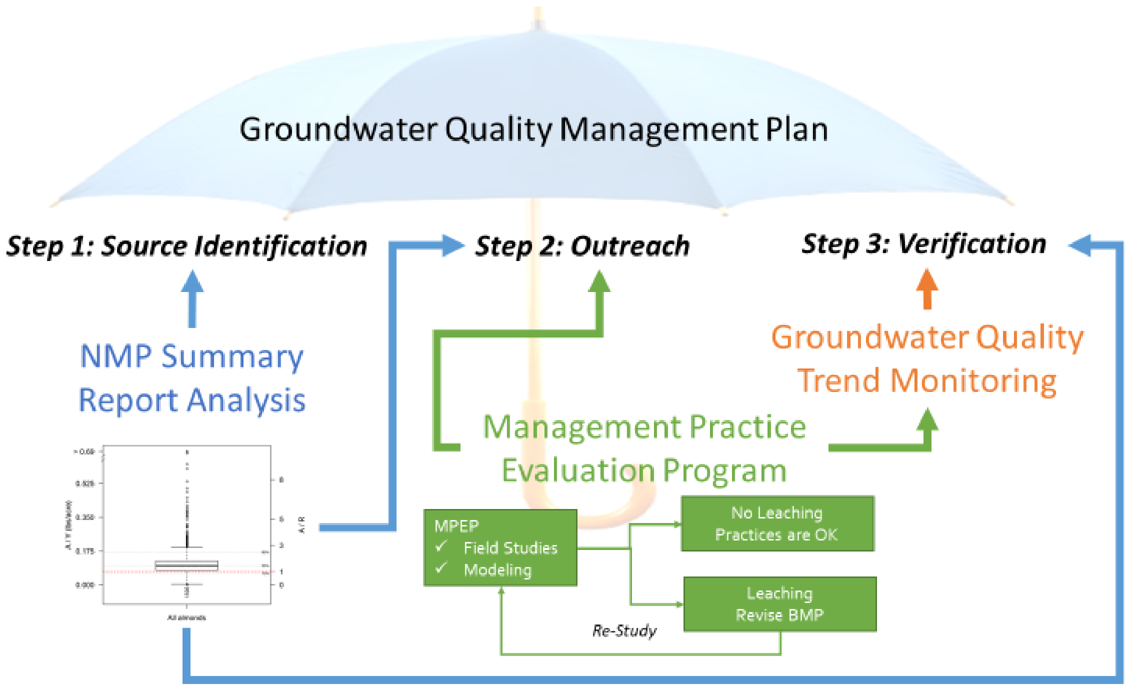
1) Identify whether site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability areas.
2) Determine if commonly implemented management practices are improving or may result in improving groundwater quality.
3) Develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern or equivalent method approved by the Executive Officer, must be provided.
4) Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

To address these four objectives, the MPEP will be implemented in three phases that overlap in time: Phase 1, gather information about management practices already demonstrated to help reduce nitrate discharges to groundwater in selected agricultural settings (Objective 1); Phase 2, field scale modeling using Hydrus, landscape-level modeling using SWAT including calibration and validation, and potentially, field studies (Objective 3); and Phase 3, assess the impacts of management practices on groundwater quality (Objectives 2 and 4).

The primary constituent of concern for the MPEP studies is nitrate although other constituents are constituents of concern (COC) for the MPEP GCC coalitions including salt and some pesticides. Northern MPEP GCC activities will include modeling of the effect of various management practices on the amount of nitrate moving past the root zone. The purpose of the MPEP activities are to develop an understanding of the relative efficacy of management practices in preventing leaching of nitrate specifically, and other soluble constituents in general.

Although the MPEP is a collaborative effort among the six northern coalitions, it is a critical element of groundwater management within each coalition region. By addressing the four MPEP objectives above, information will be generated that will be provided to growers through outreach to assist them with nutrient management and inform them regarding practices that are protective of groundwater quality (Figure 2). Outreach is fundamental to the implementation of each Coalition's GQMP strategy. As a result of the outreach, growers implement additional management practices which result in reduced leaching of nitrogen. The reduction in leaching is reflected in greater nitrogen use efficiency and improved measures of grower performance such as the ratio of N applied to N removed (or A – R).

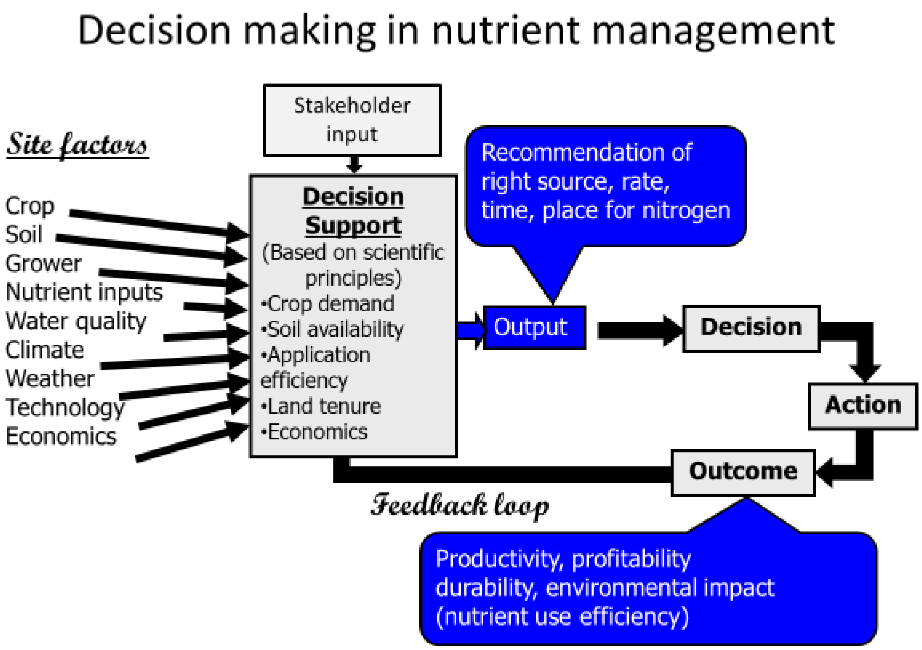
FIGURE 2. THE ROLE OF THE MPEP IN PROVIDING INFORMATION USED IN OUTREACH TO GROWERS. OUTREACH FOCUSES ON MANAGEMENT PRACTICES IDENTIFIED THROUGH MPEP ACTIVITIES AS PROTECTIVE OF GROUNDWATER.



Each Coalition's Farm Evaluations (FEs), Nitrogen Management Plan Summary Reports (NMP SRs) feed information into the MPEP efforts, and in turn, the information generated by the MPEP on the effectiveness of management practices will be used by each individual coalition to guide their GQMP activities and allow them to meet their coalition's individual performance goals and performance measures. This interaction among WDR elements is explained in greater detail below.

Although the purpose of the MPEP is not to develop a decision support system for growers to assist with nitrogen management, it should be recognized that nutrient management is a complex process that involves far more than simply applying a specific amount of nitrogen to the field (**Figure 3**). To maximize yield, several site-specific factors need to be considered in addition to factors such as crop nutrient demand, nutrient content of the soil, and the cost of inputs. This information is used to make decisions about the right time to fertilize, the right placement of the fertilizer, the right source and right amount of fertilizer. Together, these four R's determine the success of the grower. However, they also determine whether nutrient inputs are managed correctly. If managed correctly, nutrient inputs remain where the crop can utilize them, minimizing the amount leached past the root zone.

FIGURE 3. THE FACTORS THAT IMPACT DECISIONS ABOUT NUTRIENT APPLICATIONS AND MANAGEMENT (ADAPTED FROM FREP).



MPEP – Detailed Approach

The northern MPEP GCC Work Plan includes three phases focused on addressing the four objectives,

1. Phase 1 – Inventory of Effective Management Practices
2. Phase 2 – Modelling and Field Studies
3. Phase 3 – Assessment of Management Practices on Groundwater Quality

Phase 1 – Inventory of Effective Management Practices

There are two purposes for conducting an inventory of management practices by reviewing the relevant literature. First, if reliable information is available to conclude that a practice(s) can be effective in reducing leaching of nitrogen under a specific set of conditions, that information can be provided to growers immediately. The practices identified during the literature review may not be possible to extend to every field as not all practices are equally effective in all locations, soil types, or crops. Consequently, the evaluation of practices will consist of the list of management practices, the state of the knowledge about their effectiveness in reducing leaching, caveats (e.g. not effective on sandy or clay soils), and degree of uncertainty about their efficiency in reducing leaching of nitrate. As the MPEP continues over time, the MPEP GCC will augment the list of effective practices.

Many of the practices identified to date have been studied in locations outside the Central Valley of California. Consequently, it is not clear if their ability to reduce leaching of nitrate below the root zone is similar under the soil and climatic conditions found in the MPEP region. Discussions with experts on the MPEP TAC will also be used to verify the information from the literature, and complete the review.

Phase 1 Deliverable

The MPEP GCC has developed an annotated list of studies and management practices that were identified during the literature review. The list provides a suite of practices from which growers can choose to implement on their farming operation.

An initial list of studies evaluated during the literature review and the literature sources are provided in **Appendix A**. The full list will be available to the Regional Water Board on request and will be used by the MPEP GCC member Coalitions in their outreach to members on groundwater protection.

Management Practices Outreach

There is a wide range of management practices used by members on their farming operations. Coalition outreach efforts to date have focused on using nitrogen fertilizer according to the "four R's" developed by the International Plant Nutrition Institute (IPNI); right place, right time, right rate, and right source. This framework for practices resonates with growers making adoption of new practices a relatively straightforward process. The practices identified during the literature review can all be placed into the context of the 4R's. Consequently, outreach efforts in the future will continue to focus on the four R's. Superimposed on these fertilizer management practices are irrigation management practices that are important in reducing nitrate from being moved below the root zone. Several practices are reasonably assumed to help reduce nitrate discharges to groundwater in high vulnerability areas including accounting for nitrate in groundwater (if used as a source of irrigation water) in a crop nitrogen management plan, and injecting nitrogen fertilizer into drip or microsprinkler irrigations at times that match plant demand and consumption of nitrogen.

Phase 2 – Modeling and Field Studies

Determining if management practices are improving or may result in an improvement in groundwater quality (Objective 2) requires modeling at both the field level and the landscape level, and linking the modeling results to impacts on groundwater quality. Phase 2 focuses on the modeling efforts and any field studies necessary to guarantee that the modeling results are as accurate as possible. The linkage of landscape-level modeling to groundwater quality occurs during Phase 3.

Landscape-level Modeling – SWAT

SWAT has been used extensively to investigate the impact of management practices on surface and groundwater quality in large basins across the world. The SWAT model is currently being used by the SSJV coalitions in their MPEP to evaluate the effects on nitrate leaching of management practices implemented on the land surface. Through other projects, the SWAT model is parameterized for a large portion of the Tulare Basin and has been used to evaluate the impact of management practices on the concentration of nitrate in groundwater in the Alta Irrigation District region.

Extending the domain of the model out of the Tulare Lake Basin requires the acquisition of large amounts of data and a reasonable time period to parameterize and calibrate the model. Initial baseline model runs were initiated in 2017. There are currently no technical barriers that prevent the model domain from being expanded to the entire Central Valley. Model refinements and subsequent model runs are scheduled for the second and third years, and perhaps beyond. Deliverables for the NRCS CIG grant include input files and model results for the entire Central Valley. The northern MPEP GCC will take the input files and model results from the first year's modeling efforts and initiate work on evaluating the effects of specific management practices on nitrate leaching within the northern MPEP GCC region. As the model is refined in later years, the northern MPEP GCC will continue to evaluate the effect of management practices on nitrate leaching. Refinements may allow more accurate estimates of nitrogen leaching past the root zone but are not expected to change the relative efficiency of various practices. I.e., if results of the baseline model indicate that four split applications result in less leaching than two split applications, the refined model(s) will retain that relative efficiency.

Models are mathematical representations of processes that occur on the landscape. These representations are in the form of equations that have terms representing physical processes such as precipitation, air temperature, or infiltration rate of water through soil. To each of these terms, a numeric value is assigned. Sometimes these values vary based on the location and time period over which the model is run. Some of these parameter values are known with a great deal of accuracy, others are estimated using available data from the region. For example, evapotranspiration (ET) can be estimated using data from the California Irrigation Management Information System (CIMIS) but those data are for large regions and may not be accurate for any specific parcel on the landscape within that region. Generally, these estimates are sufficient to achieve reasonable accuracy for the model results, but if more accurate results are desired, understanding ET on a much finer scale may be necessary. These data may take additional time to generate.

SWAT and Hydrus (see below) have dozens of parameters. Some of these parameters have large effects on model results such as nitrate leaching, some parameters have little effect on model results. Understanding the relative impact of model parameters on model results can be obtained by performing a sensitivity analysis. Sensitivity analysis investigates the variation in the output of a numerical model as a result of the variation in the input parameters. The result of a sensitivity analysis is a ranking of the "relative importance" of parameters on model results. These rankings can be used to guide the acquisition of additional/better data to be used as parameter estimates. For example, a recent study determined that SWAT model parameters governing surface water runoff due to rainfall were the most sensitive overall, but were primarily important in areas with both rainfall and snowfall[1]. This example illustrates that the specific location modeled can determine which parameters are important in an analysis.

Additional/better data can be obtained in several ways, one of which is to perform field investigations. The northern MPEP GCC will perform sensitivity analyses on SWAT model runs using the sensitivity module available from the SWAT developers. These analyses will be performed during the year immediately following the availability of model input and output files from the SSJV MPEP group. The results of the sensitivity analyses will be used to guide the design of the field investigations. These investigations could range from obtaining site-specific ET values, studies of soil infiltration rates, to the amount of rainfall at specific locations. While the field investigations may involve large multi-year studies of nitrate fate and transport, they could also involve smaller studies of soil carbon content if it appears that soil carbon content is an important factor that determines nitrogen leaching.

It is not possible to identify a priori the number of model parameters that will be the subject of field investigations. The MPEP GCC will develop the criteria by which the results of the sensitivity analyses will be interpreted and the most sensitive field parameters are identified.

Throughout the modeling process, the model will be refined to improve the evaluation of management practices. Refinement can involve numerous aspects of model modification including 1) better crop growth models that are more accurate for various portions of the Central Valley, 2) better understanding of land use across the landscape, 3) better estimates of crop yield, and 4) better parameter estimates for various parameters in the model.

Calibration and validation are essential elements of model development. The calibration and validation efforts will employ data to adjust the model to improve its ability to represent cropping systems in the area (calibration), and then to check output against actual measurements for comparable situations (validation). Data sources might include the following:

- Management and agronomic information from commercial fields, such as data summaries by Agricultural Commissioners and DWR
- Raw data collected by growers
- Field study and modeling (e.g., Hydrus) results from the literature and gray literature [i.e., from unpublished work]).

For additional details, see Section 3.8.3 on page 3-46 of the SSJV MPEP Work Plan (submitted September 2017).

Site-specific Modeling - Hydrus

Hydrus is a physical based model that is used to understand fate and transport of constituents, such as nitrate, at specific locations, e.g., a single walnut orchard in the San Joaquin Valley. The model uses the first principles of physics and chemistry to examine the fate and transport of constituents such as

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[1] Veith, T.L., M.W. Van Liew, D.D. Bosch, and J.G. Arnold. 2010. Parameter sensitivity and uncertainty in SWAT: a comparison across five USDA-ARS watersheds. Transactions of the ASABE. 53:1477-1486.

nitrate. It can be run as a 1-dimensional, 2-dimensional, or 3-dimensional model to simulate water, heat, and solute transport through variably saturated porous media. Used for vadose zone modeling, it can be extended to perform the simulations in the saturated zone (groundwater). To run the model and accurately simulate nitrate leaching, a reasonably large amount of information is needed about soils, water and nitrate flux. The model can be run without additional modules for more complex biogeochemical reactions if desired.

Because of the large amount of data needed to parameterize the model, Hydrus is most appropriately used at the level of an individual field. Hydrus will be used, when necessary, to better understand the ability of management practices to reduce leaching of nitrate at individual locations throughout the MPEP GCC region.

Although the sensitivity analyses described above were framed as an exercise involving the SWAT model runs, a similar process will be used to determine input parameter sensitivity of Hydrus parameters. Hydrus will be used to investigate the relative efficiency of management practices at specific sites in the northern MPEP region.

Crop prioritization

The northern MPEP GCC is unable to investigate management practices on all crops simultaneously. As a result, the northern MPEP GCC will submit a crop prioritization analysis within 60 days of the submission of this work plan. The northern MPEP CCG is determining if there will be a single priority crop list for all member coalitions, or if the priority list should be modified by region. The prioritization process will use a combination of crop acreages and recommended fertilizer application rates to arrive at a ranking of the crops potentially most likely to generate the biggest mass of nitrate leaching to groundwater. Delaying submission of the crop prioritization list to the Regional Water Board by 60 days will not delay the evaluation of management practices as the initial SWAT model for the Valley will not be released until April or later.

Field Studies

The northern MPEP GCC may contribute funds and/or apply for grant funds to conduct field studies if it is determined that these studies will contribute to a better understanding of the effectiveness of management practices or allow a better parameterization of the models. These studies will be referenced in the MPEP Annual Updates including the lessons learned from the implementation of the study designs and results of the study regarding effective management practices. The MPEP GCC will work with the GCC TAC to remain informed of other studies results regarding effective management practices that could be adopted by growers.

The MPEP GCC has committed funds to an existing study that was implemented in 2016 and funded by CDFA. CURES received a grant from CDFA FREP to perform a study to investigate nitrate leaching past the root zone in walnuts. The study was initiated in March 2016 and will be completed in June 2018. Each of the MPEP GCC Coalitions is contributing financially to the project. CURES will use the results from the study to better quantify SWAT model parameters when possible, and generate additional outreach information for Coalition members growing walnuts. The proposal with the design is provided as **Appendix B**.

Phase 2 Schedule

Phase 2 will be implemented in coordination with the SSJV MPEP. The specific schedule for modeling with SWAT and Hydrus that the northern MPEP GCC will follow for Phase 2 of its work plan is provided in Figures 3-1A and 3-1B (pages 3-3 and 3-4 in the SSJV MPEP Work Plan submitted October 2017) in the SSJV MPEP Work Plan. Work on completing SWAT 1.0 was initiated in late 2016, and additional refinements will occur annually through 2023. Each set of refinements also involves model runs with specific management practices to evaluate the impacts on groundwater quality.

Phase 2 Deliverable

Progress on each of the model refinements will be provided in the MPEP Annual Updates from each of the northern MPEP GCC member coalitions. All model inputs and outputs are publicly available through the USDA.

Phase 3 – Assessment of Management Practices on Groundwater Quality.

While SWAT modeling results provide a good representation of the output of water and constituents from root zones, another step is needed to characterize the influence of these constituents on underlying groundwater. Several approaches can be used, and each helps to tell part of the story.

1. **Root zone outputs** for several scenarios can be used along with information on rates of practice use/adoption to describe how the output of nitrate changes over time. This provides information about how specific crop groups and locales are performing, and how performance is changing, relative to the goal of reducing nitrate loads to groundwater. No specific groundwater analysis is required for this type of evaluation.
2. **Representative data sets** derived from SWAT runs can be used to provide surface loading inputs to groundwater model runs. An example of this approach was implemented in the Alta Irrigation District study (LWA Team, 2016)[2]. This assessment can incorporate information about other recharge sources (e.g., losing streams, groundwater recharge augmentation facilities, natural recharge through non-agricultural lands, septic systems, wastewater facilities),
3. Over the long-term, comparisons of landscape-level changes in recharge quality and quantity (from items 1 and 2, above) and observations from **groundwater quality trend monitoring**.

Phase 3 Schedule

The initiation of Phase 3 depends on the refinement of the SWAT model. As the SWAT model becomes available and useable, the northern MPEP GCC will submit a technical memo to the Regional Water Board to provide more details about the schedule and deliverables of Phase 3. This will occur no later than January 31, 2020.

Phase 3 Deliverable

Progress on Phase 3 will be provided in the MPEP Annual Updates from each of the northern MPEP GCC member coalitions. Any formal deliverables from Phase 3 will be described in the technical memo described above.

[2] Larry Walker & Associates, et. al. 2016. CV-SALTS Management Zone Archetype Analysis: Alta Irrigation District.

MPEP Objectives

Phases 1 to 3 will be implemented to address the four MPEP objectives. Each of these objectives directly or indirectly require an assessment of the effects of management practices on the leaching of nitrate and their impact on groundwater quality. The objectives are addressed in more detail below.

Objective 1: Identify whether site-specific and/or commodity-specific management practices are protective of groundwater quality within high vulnerability areas.

Addressing this objective requires that two separate exercises are completed; identification of management practices in place on member farming operations in high vulnerability areas, and developing an understanding of the effectiveness (or lack thereof) of those practices. Objective 1 will be addressed in Phase 1 of the MPEP GCC Work Plan as well as in the progress reports within each individual coalition's GQMP (identify, validate and implement management practices to reduce loading of COC's to groundwater).

A baseline of management practices generated from FE data can be georeferenced within both low and high vulnerability areas. As additional management practices are added by members on their farming operations, these can be tracked by using subsequent reporting by members to their coalitions.

The other type of information is the relative effectiveness of the management practices, i.e., the level of groundwater protection offered by the use of these practices. The northern MPEP GCC interprets protective as the concentration of nitrate that will not impair the beneficial uses of groundwater. The northern MPEP GCC will use the approach of evaluating the effectiveness of several practices and making a determination of which practices are more effective in reducing leaching of nitrate under specific model or field conditions (Phase 2). Practices that minimize leaching of nitrate will be considered more protective than those with higher leaching rates. A literature review assessing current information regarding protective practices and how they impact nitrogen leaching was completed in Phase 1 and will be added to by the MPEP GCC as additional literature becomes available.

The MPEP is designed to evaluate management practices and their effectiveness in reducing the leaching of nitrate past the root zone. The MPEP GCC assumes that qualitatively, a reduction in the mass of N leached to groundwater means that over time, groundwater will not degrade further. Depending on the amount of water reaching groundwater, this reduction may also result in an improvement in water quality. Consequently, the tasks required to demonstrate no further degradation, and possible improvement in groundwater quality, involve demonstrating that management practices implemented on member farming operations over time are reducing the mass of nitrate leaching to groundwater. The rate at which improvement in groundwater quality occurs depends on several factors including (but not limited to) the concentration of nitrate in the groundwater aquifer, the volume of water in the aquifer, and the transit time for nitrate to reach groundwater after leaching past the root zone.

The MPEP GCC's approach to demonstrating that there is a decreasing mass of nitrate leaching past the root zone will be accomplished primarily through the SWAT and/or Hydrus modeling and when appropriate, through field studies of the effectiveness of management practices. Because of the uncertainty in parameter values used in the SWAT or Hydrus models, it will not be possible to calculate the mass reduction associated with implementation of specific management practices with any real accuracy, but it will be possible to rank the effectiveness of practices in reducing leaching as explained in the section above. Estimating the reduction in the mass of nitrate leached to groundwater satisfies the requirement provides the information necessary to address the requirement below.

The process involved in using the SWAT or Hydrus models to evaluate the effectiveness of management practices is straightforward. A baseline model run is performed that represents a part of the landscape with no management practices in place. Additional model runs are made keeping all of the parameters the same except for those "changed" by a management practice. For example, model runs can consist of comparing a single application of nitrate, two applications, and four applications, all with the same total amount of applied N. The only differences in the model runs are the number of applications, the amount of N used in each application, and the timing of the applications. All other model parameters remain the same, for example the irrigation schedule. Any differences in the amount of nitrate moving past the root zone are the result solely of the differences in the timing of the applications. For this hypothetical example, let's assume that the model indicates that the amount of nitrate leaching past the root zone decreases when the number of applications is increased from 2 to 4 while maintaining the same yield. As a result of the model runs, the Coalitions can inform their members that 4 applications with less nitrate per application is more effective in preventing leaching (i.e., more protective) than 2 applications or a single application, and does not result in a loss of yield.

Because of the extreme diversity of soils, climate, and cropping conditions across the northern MPEP GCC region, only a small portion of those conditions can be modeled specifically. While the conservative assumption is that a protective practice under conditions that result in elevated rates of leaching will also be protective in soils with low leaching, the northern MPEP GCC does not want to make the assumption that the most conservative management practices should be implemented everywhere. Implementing overly conservative management practices in locations where there is no resulting measurable decrease in leaching rate is a wasted investment on the part of the member. Consequently, the northern MPEP GCC will review results of modeling runs to, 1) inform future model runs, 2) inform outreach to growers about the efficacy of management practices, 3) guide the implementation of field studies, and 4) determine if member's current practices are protective of groundwater.

The practices to be evaluated will be selected using the 4 R's as guidance. The 4 R's include: right time, right place, right rate, and right source. Many of the management practices that fall under one of the 4 R's cannot be modeled or incorporated into a field study directly. For example, performing soil N analysis and plant tissue analysis are not part of a model. However, if these tests result in adjustments of the amount and/or timing of the nitrate applied, these changes can be incorporated into the MPEP modeling and field studies. The Coalitions will be able to evaluate changes in practices associated with changes in nitrogen applied through the information contained in the FEs and NMPSRs, respectively. This information can be integrated into future SWAT modeling efforts to evaluate the effectiveness of specific practices on a landscape scale. Growers can be informed that soil and tissue testing with the goal of optimizing applications to maximize nitrate uptake and yield will also result in reduced leaching.

Right Source

The right source of nitrate is determined by a specific set of conditions that include soil physical and chemical properties, the appropriate plant-available form, synergisms among nutrient elements, and fertilizer blend compatibility. Nutrients can be applied in forms that are immediately plant-available or that converts into a plant-available form over time in the soil. Chemical properties of the soil such as elevated pH indicates that sources such as urea should be avoided. Making sure that different elements such as phosphorus and nitrogen are provided/available in the appropriate ratio promotes the full use of nitrate in the soil. Understanding which nutrient is limiting plant growth can promote the uptake of all nutrients and the reduced leaching of nutrients. However, understanding the appropriate blend with respect to granule size prevents segregation of the products during application. Also, certain combinations of sources can attract moisture during mixing limiting the uniformity of the application of the blended material leading to overapplication and leaching in some areas of the field.

Right Rate
Yield is directly related to the quantity of nutrients taken up by the crop. To determine the amount of nutrients to apply, a meaningful yield target should be established. Using plant and soil analysis allows the grower to determine how much of which nutrients should be added to the soil to reach the yield target. For soil amendments such as biosolids, compost, and manure, understanding the amount of nitrogen present and the rate at which that nitrogen becomes plant-available are important considerations. Understanding the amount of nitrate present in irrigation supply water is an essential part of nutrient management. Synthetic fertilizer can be used to supplement these other sources. Using synthetic nitrogen fertilizer as the final supplement can keep the cost of production low and reduce the amount of nitrate leaching past the root zone. It is also possible that due to heterogeneity in the soils in a field, different application rates may be necessary even within a single field.

Right Time
Growers must develop an understanding of the nutrient demand curve for their commodity to optimize the conversion of nutrients to plant growth and yield. Applications of nitrate before or after nutrient demand is likely to result in loss of nitrate to groundwater, and unless additional nitrate is added during periods of crop demand, will result in yield loss. Understanding when nutrient leaching occurs is critical to meeting nutrient demand and maximizing yield.

Right Place
The right place means positioning the nitrate in a position where the plant can use it. The core scientific principles that determine the right place are:

- Placement where nitrate can be accessed by the roots,
- Consider soil chemical reactions that can improve or reduce nutrient availability,
- Consider the tillage system which can demand that nutrients are placed in the subsurface rather than on top of the soil, and
- Understanding the spatial variability in soils in the field which can result in greater leaching and reduced yield within a single field

Objective 2: Determine if commonly implemented management practices are improving or may result in improving groundwater quality.
This objective is essentially the same as the first objective albeit on a larger geographic scale than the first objective. Developing a deeper understanding of which practices can be used to reduce leaching will occur through the SWAT and Hydrus modeling. Once the models are parameterized for a variety of conditions, the effect of different management practices on leaching can be explored. For the SWAT model that covers the entire northern MPEP landscape, this may involve carving out smaller regions and if necessary, fine tuning the parameterization of the model to those local conditions. The model can

then be run using a variety of different management practices or variations of the same practice (e.g., splitting applications multiple times) and the results compared to determine the most effective practice(s) in terms of maintaining crop yield and eliminating leaching of nitrate. Hydrus modeling is already running at the scale of an individual field allowing an evaluation of effect of different practices on leaching.

Although the fundamental approach is to vary one practice at a time and determine the effect on nitrate leaching, growers may use a suite of practices to manage nitrate applications and leaching. Once a reasonable number of individual practices are evaluated one-at-a-time, combinations of practices can be evaluated. Depending on the size of the landscape modeled (which determines model run time), modeling an exhaustive combination of practices may not be practicable. However, a sufficiently large number of combinations should be possible to model to provide the information necessary to inform outreach.

This objective has the added element of linking movement of water and nitrate past the root zone to groundwater quality. The results of the analysis for the first objective can be extended to the second objective by using the SWAT and/or Hydrus output as input to a groundwater model. SWAT provides the output of water and nitrate (and other constituents of concern) at the bottom of the root zone allowing an estimate of the loading of these inputs to groundwater models. Hydrus also generates the amounts of water and nitrate migrating down through the vadose zone and can be linked directly with groundwater models. The direct linking of Hydrus with a groundwater model facilitates estimating the impact of management practices on groundwater quality. However, Hydrus is meant to run on a very small geographic scale relative to the size of the northern MPEP coalitions or even groundwater subbasins. Therefore, it is likely that most of the work on this objective will be performed using SWAT output.

Linking SWAT output to groundwater quality models is not a trivial exercise. In addition to inputs from irrigated agriculture, there are other inputs of water to groundwater basins including impoundments, streams and rivers, and precipitation. Linking to a groundwater model will be done in the same manner as presented in the CV-SALTS Management Zone Archetype Analysis: Alta Irrigation District.

The other approach to determining whether groundwater quality is improving is groundwater monitoring. The coalitions are involved in developing their groundwater quality trend monitoring program which are expected to generate a significant amount data that can be used to characterize the status and trends in groundwater quality over time.

The Groundwater Trend Monitoring Programs of each Coalition will provide the data necessary to identify long-term trends in groundwater quality. Current groundwater quality has taken years to decades to develop. It may take an equally long period of time to demonstrate improvement. Therefore, the short-term measure of progress toward improving groundwater quality is based on the metrics that each coalition developed in their individual Groundwater Quality Management Plans. Progress in meeting performance goals and measures associated with these metrics will be discussed in individual meetings between each coalition and Regional Water Board staff.

Objective 3: Develop an estimate of the effect of Member's discharge of constituents of concern on groundwater quality in high vulnerability areas. A mass balance and conceptual model of the transport, storage, and degradation/chemical transformation mechanisms for the constituents of concern or equivalent method approved by the Executive Officer, must be provided.

This question is essentially the same as the one above with an added focus on the high vulnerability areas within the Coalition's regions. Therefore, the northern MPEP GCC will use an approach similar to the one described above to address this issue.

Objective 4: Utilize the results of evaluated management practices to determine whether practices implemented at represented Member farms (i.e., those not specifically evaluated, but having similar site conditions), need to be improved.

Management practices implemented on member farming operations are tracked by each coalition including irrigation method and amount, nitrogen application rates, and timing of applications. The SWAT and Hydrus model runs will be used to identify those practices that are considered more protective of groundwater under the conditions of the model runs (e.g., soils, ET_c, precipitation). Comparisons of practices used on member farms can be compared with practices that are considered more protective under the specific local conditions at those farms. If it appears that more protective practices can be implemented, these members will be contacted about the potential for the implementation of the more protective practices. If the more protective practices require a substantial financial commitment, the individual coalitions will provide their member with information on where the member can go for assistance.

Integration of MPEP with other WDR elements

The WDRs require that both members and Coalitions become involved in several elements related to groundwater quality. These elements are focused on minimizing the amount of nitrate leaching, documenting that practices are implemented, and monitoring groundwater quality to document trends.

Member responsibilities:

- Submit to the Third-Party information on implemented management practices (e.g. Farm Evaluation Plan); timing of requirement is based on vulnerability.
- Complete the Nitrogen Management Plan (NMP) Worksheet to document their nitrogen management for the upcoming crop year based on expected yields.
- Submit to the Third-Party the amount of nitrogen applied and actual yield (Nitrogen Management Plan Summary Report) to document their nitrogen management plan worksheet – requirements are based on vulnerability status
- Implementation of Management Practices Protective of Surface and Groundwater as identified through the Surface Water Quality Management Plan and the Groundwater Quality Management Plan; results of the MPEP will be utilized to determine practices that are protective of groundwater

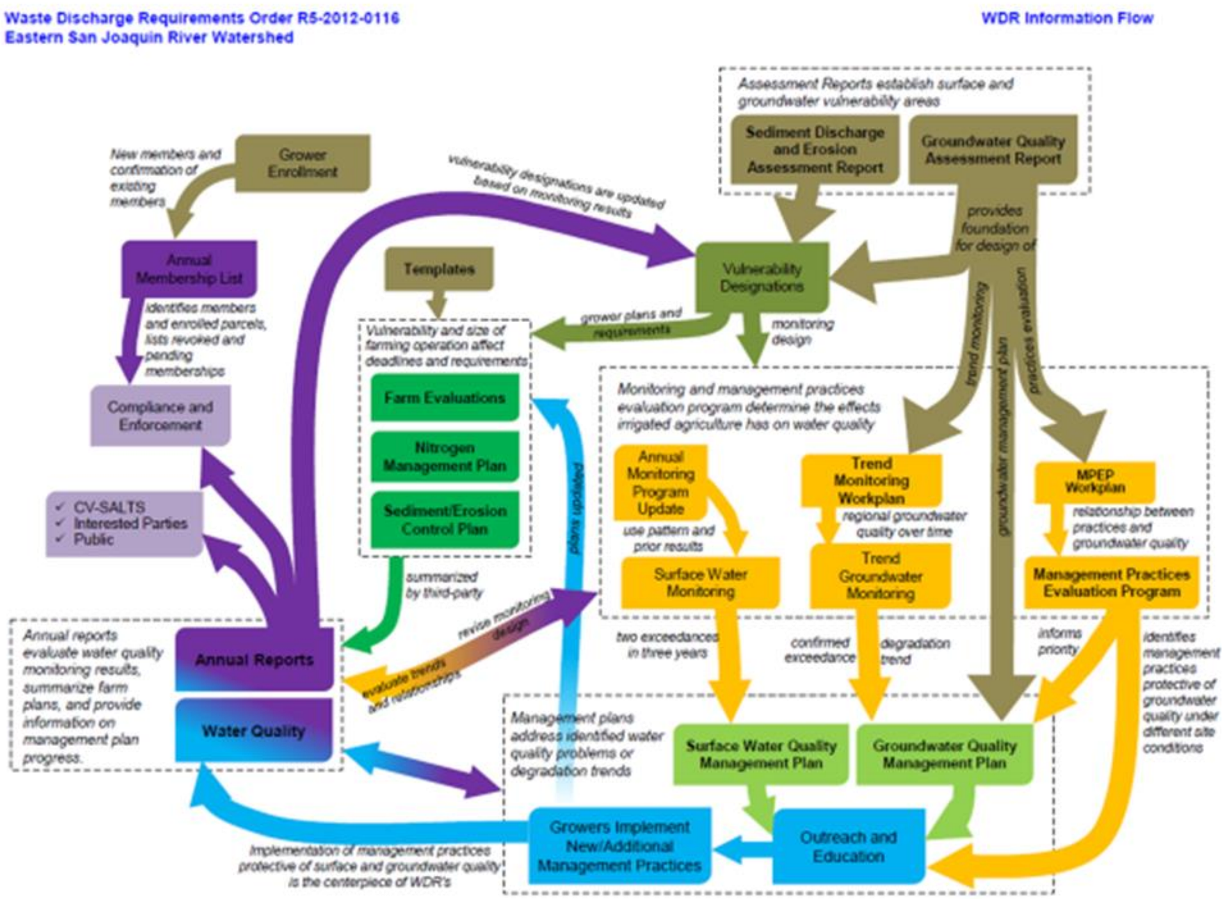
Coalition responsibilities:

- Management Practices Evaluation Program – Third Parties implement the MPEP GCC Work Plan, submit updates to the Regional Water Board annually and every 6 years as a report.
- Groundwater Assessment Report – Third Party, submit to the Regional Water Board every 5 years.
- Groundwater Quality Management Plan – Third Party, submits annual updates to the Regional Water Board.
- Groundwater Quality Trend Monitoring Program – Third Party, submits to the Regional Water Board a work plan for a trend monitoring network, submits annual updates to the Regional Water Board

To address these challenges, the Coalitions implemented several interacting programs to facilitate compliance with the requirements of the Orders; these programs include the submission of information on irrigation and nitrogen management practices (FEs) and nitrogen applications (NMPSRs), development of appropriate reporting metrics (NMP TAWG), the implementation of effective management practices (GQMP, MPEP), and the monitoring of groundwater quality to document improvements (GQTM). The Regional Water Board developed a schematic illustrating the links among these programs and deliverables (

Figure 4). The programs are described briefly below.

FIGURE 4. RELATIONSHIP AMONG WDR PROGRAMMATIC ELEMENTS AND REQUIRED GROWER AND THIRD-PARTY DELIVERABLES. FIGURE FROM REGIONAL WATER BOARD.



Groundwater Quality Management Plan

Each Coalition is required to develop a Groundwater Quality Management Plan (GQMP) which outlines the process that Coalition will follow to improve groundwater quality. The GQMP establishes a set of performance goals and measures that ensure that the management plan leads to an evaluation of management actions to determine if adequate progress is being made toward improving groundwater quality. Implementation of practices is tracked through Farm Evaluation Plans and Nitrogen Management Plans, and improved water quality is tracked through the Groundwater Trend Monitoring Program.

Farm Evaluation Plans

Members are provided with a survey that requests information about management practices used on their farming operation including erosion control, prevention of discharge of agricultural chemicals to surface water, and practices in place that are understood to minimize the discharge of agricultural chemicals to groundwater (e.g. wellhead protection). The surveys are distributed to all members and are returned to the Coalitions each year.

NMP Technical Advisory Work Group (NMP TAWG)

Metrics must be reported by members to the Coalitions to allow an evaluation of their nitrogen applications, the amount of nitrogen removed from the fields, and the potential risk for leaching nitrate to groundwater. To assist the Coalitions and Regional Water Board with the development of an appropriate metric, a technical advisory workgroup was formed. The NMP TAWG process involved experts from State and Federal government agencies, academia including both UC faculty and UC Cooperative Extension personnel, commodity groups (e.g. tomatoes and almonds), and industry (International Plant Nutrition Institute). The TAWG met numerous times and recommended that growers report the amount of nitrate applied, and the ratio of nitrogen applied to yield. From these two metrics, the Coalitions calculates the yield from each field. As per requirements from the Regional Water Board, the yield of many crops can be converted to the amount of nitrogen removed by multiplying the yield by a crop conversion constant (converts yield on a per acre basis to the amount of N removed per acre). All ILRP Agricultural Coalitions recently submitted a preliminary list of N-removed values for approximately 98% of the acreage in the Central Valley. Once approved, the Coalitions anticipate converting yield to N-removed for crops for which the conversion values are available.

Management Practices Evaluation Program (MPEP)

As indicated above, the efficacy of many management practices in reducing leaching of nitrate to groundwater is not known. The MPEP is the vehicle for evaluating the effectiveness of management practices that can be implemented to protect groundwater (reduce leaching of nitrate past the root zone). To conduct the modeling necessary to evaluate the efficacy of management practices across the Central Valley, the northern and southern coalitions have coordinated efforts to effectively utilize available resources and obtain a parameterized model within the first few years of the program.

Groundwater Quality Trend Monitoring (GQTM)

Once management practices are implemented, there is the expectation that groundwater quality will improve. The Groundwater Quality Trend Monitoring program is the vehicle to document improvements in groundwater quality over time. Each Coalition is developing their individual groundwater monitoring network and monitoring work plan that will be able to document improvements in water quality. What is unclear is the time necessary for each Coalition’s monitoring program to detect improved groundwater quality. Because the transit time for nitrate applied to the surface may be decades in many areas, it is expected that improvements will not be immediate. Consequently, it is expected that any improvement in groundwater quality will not be detectable for a significant period of time.

Several of the ILRP Agricultural Coalitions formed a Central Valley-wide Groundwater Regional Monitoring Program. Called the Central Valley Groundwater Monitoring Collaborative (CVGMC), the group currently consists of several ILRP coalitions, but is envisioned to eventually include all dischargers of salt and nitrate in the Central Valley. The CVGMC is developing a trend monitoring program that can serve as the Surveillance and Monitoring Program (SAMP) as required by the CV-SALTS basin plan amendment process. The conceptual approach was developed and a work plan submitted on October 31, 2017. After its conditional approval, the CVGMC agreed to submit a technical work plan by May 16, 2018. Prior to submission, the CVGMC and the Regional Water Board will hold several meetings to discuss the development of the technical work plan. The goal is to have all coalitions monitoring groundwater during the fall of 2018.

Integration

Growers are expected to implement the practices vetted through the MPEP, and report the implementation through the Farm Evaluation Plans. Nitrogen Management Plan Summary Reports (depending on the practices implemented) provide an estimate of the potential risk to groundwater through the use of the A/R or A/Y metrics. The Coalitions also will report on the implemented practices in their annual reports. Finally, improved groundwater quality is documented through the groundwater quality trend monitoring and reporting.

TABLE 3. ELEMENTS OF THE WASTE DISCHARGE REQUIREMENTS AND INFORMATION OBTAINED.

Information Obtained from Required Elements	Farm Evaluation Plan	NMP Worksheet / Summary Report	NMP Summary Report Analysis	NMP TAWG	GAR	GQMP	GTMP	MPEP
Responsible Party	*Grower*	*Grower*	*Coalition*	*Coalition / Experts*	*Coalition*	*Coalition*	*Coalition*	*Coalition*
Information on management practices	X	X				X		X
Information on nitrogen applications		X	X					
Determine tool box of "right" practices (right time, right place, right type, right amount)				X				X
Education on practices, new technology, crop uptake information and leaching			X	X		X		X
Determine areas with high nitrates and prioritization of crop / location for outreach					X	X	X	
Impact of practices on crop growth		X	X	X				
Impact of practices on groundwater (field level)						X		X
Impact of practices on groundwater (landscape-level)							X	X

Member Education and Outreach

Coalition outreach efforts will be ongoing throughout the MPEP process as outlined in coalitions' GQMP. These outreach efforts will convey useful information from the MPEP and to growers.

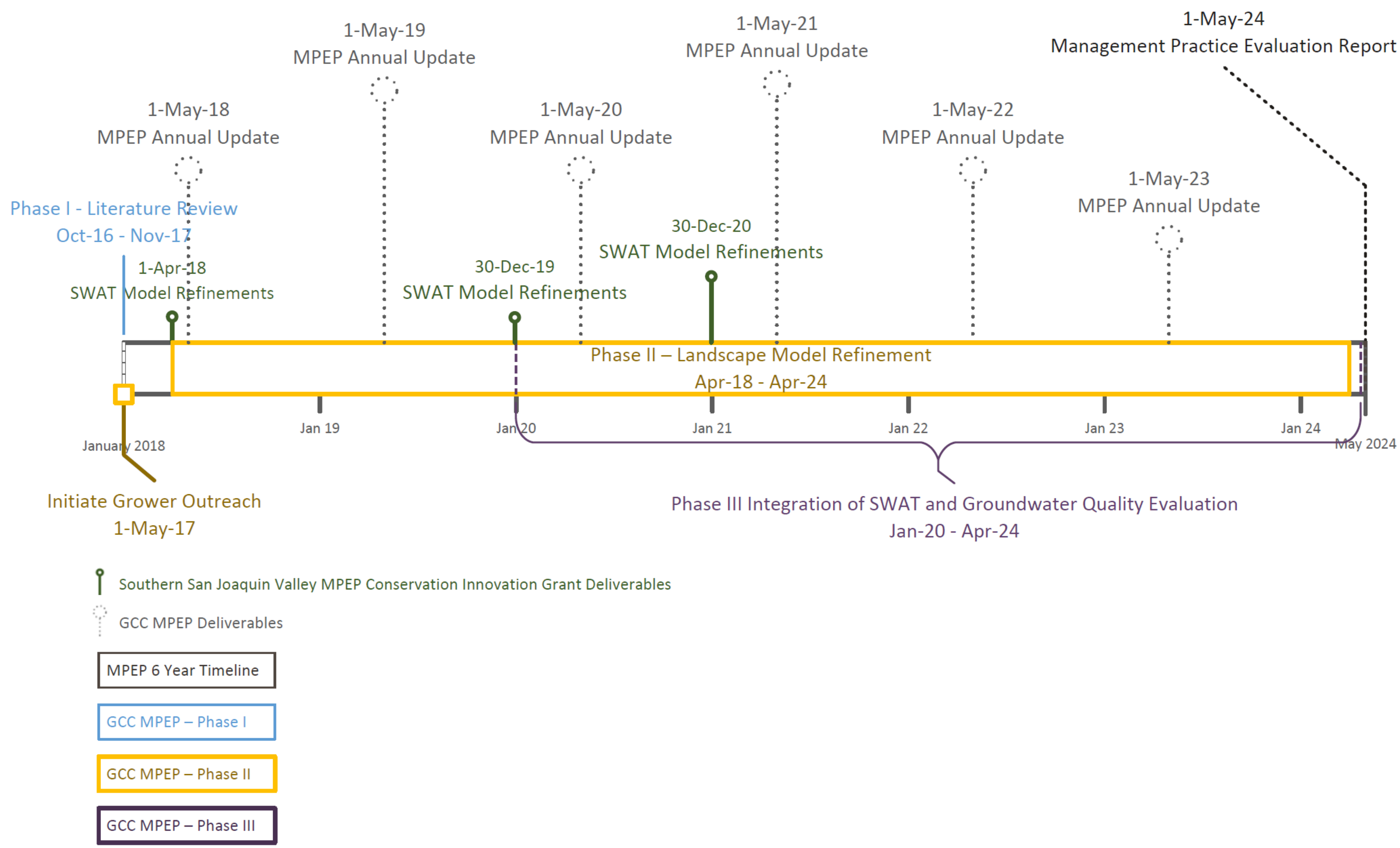
Initial outreach to growers will occur based on the results of the initial literature review. Growers will also be provided with information about management practices that have been successful in reducing nitrate leaching in the past. As the MPEP matures, additional information will be obtained about the efficacy of management practices. Each Coalition will provide information on these practices to their members as is appropriate to the crops and conditions in each Coalition region.

A methodology will be developed to extend the information obtained from the various phases to Coalition members and encourage the adoption of practices found to increase the protection of groundwater. Each Coalition has developed an approach to outreach and education that meets the needs of their membership such as, large meetings for growers, small meetings, individual outreach, literature development, mailings, and websites. Each Coalition will be able to disseminate to its members the status and results from the studies as they become available.

Timeline and Master Schedule

Phase 1 is complete although as additional practices are identified as being protective of groundwater, they will be added to the list along with any relevant documentation. Phase 2 and 3, with the exception of a brief period of time at the beginning and the end of the MPEP, will be conducted concurrently. The timeline is provided below in **Figure** 5.

FIGURE 5. GCC MPEP WORK PLAN TIMELINE FOR PHASES AND DELIVERABLES (2016 - 2024).



Appendix A - Initial literature reviewed for evaluation of management practices

Nitrogen Management Practices Protective of Groundwater

Initial Findings / References

Baram, S., (2016) – High frequency, low concentration (HFLC) vs. standard split fertigations with and without accounting for N in supply water. (With some flood events, in Pistachio and Almond in CA) Finding: timing during fertigation is most important; HFLC did give significant benefits over well timed split fertigation, and flooding flushed more N down the profile.

Hanson, B., J. Šimůnek, and J. W. Hopmans (2006) Drip tape position (surface vs. subsurface) and injection time (beginning, middle and end) of fertigation with Urea-Ammonium Nitrate (UAN) in California. The surface drip injection was more effective, and injection in the middle was most effective at improving NUE (and protecting groundwater). This paper is entirely about modeling without a groundtruthing component.

Hanson, B., J. W. Hopmans and J. Šimůnek (2008) This paper is about localized leaching of salts around a drip line (which does not require as much water as flood leaching) and no mention is made of the goal of ground water protection.

Li, Gui-Hua, et al. (2011) Coated urea improved N retention in surface and decreased N losses, as compared with uncoated urea in a corn/wheat rotation in China.

Li, Y., et al. (2015) Impacts of direct seeding rice on soil N dynamics, including leaching losses (as compared with transplanting). Maybe not the most relevant in aerobic systems, but talks about redox dynamics and about NH4 retarding N leaching.

LWA Team. 2016. CV-SALTS Management Zone Archetype Analysis: Alta Irrigation District. Prepared for CV-SALTS.

Nakamura, K., et al. (2004) Split application reduces N leaching in sand and andisol in Japan. 2 applications was sufficient for andisol, but splitting into 3 applications gave more improvements. Splitting into 6 gave no additional benefits on either soil. This is one of the most ground-truthed and thorough parameterizations of the model that I have yet encountered.

Quin, W., et al. (2016) Split application vs. lumped, wet vs. dry years, irrigation water and nitrogen annual application rates were all considered together with yield, and optimal N, applied in split application, with 80% ET irrigation had best N use efficiency (NUE) without reducing yield. (this is protective of groundwater)

Ravikumar, V., et al. (2011) This paper uses the model to make recommendations of fertigation amount, timing. Sugarcane, india, groundtruthed with tensiometers and root depth and radius throughout season.

Tafteh, A., and A. R. Sepaskhah (2012) Alternate furrow flooding of canola could prevent 50% of leaching losses under canola as compared with all furrow (continuous).

Weng-Zhi, Z., et al. (2013) This is a column experiment (no plants) to calibrate Hydrus, showing that different rates of urea application to the surface followed by different rates of water application resulted in different distributions of urea, ammonium and nitrate throughout the profile. The researcher concludes that cutting back on water can keep N from leaching, even when applying a high rate of urea.

References

Li, Gui-Hua, Lin-Ping Zhao, Schu-Xiang Zhang, Y. Hosen, K. Yagi (2011) Recovery and leaching of 15N-labeled coated urea in a lysimeter system in the North Chinal Plain. Pedosphere 21(6):763-772.

Li, Y., J. Šimůnek, Z. Zhang, L. Jing, L. Ni (2015) Evaluation of nitrogen balance in a direct-seeded-rice field experiment using Hydrus 1D. Agricultural Water Management 148:213-222.

Nakamura, K., T. Harter, Y. Hirono, H. Horino, and T. Mitsuno (2004) Assessment of root zone nitrogen leaching as affected by irrigation and nutrient management practices. Vadose Zone Journal 3:1353-1366.

Hanson, B., J. Šimůnek, and J. W. Hopmans (2006) Evaluation of urea-ammonium-nitrate fertigation with drip irrigation using numerical modeling. Agricultural Water Management 88:102-113.

Hanson, B., J. W. Hopmans and J. Šimůnek (2008) Leaching with subsurface drip irrigation under saline, shallow groundwater conditions. Vadose Zone Journal 7:810-818.

Quin, W., M. Heinen, F. B. T. Assnck, O. Oenema (2016) Exploring optimal fertigation strategies for orange production using soil-crop modeling. Agriculture, Econsystems and Environment 223:31-40.

Ravikumar, V., G. Vijayakumar, J. Šimůnek, S. Chellamuthu, R. Santhi, K. Appavu (2011) Evaluation of fertigation scheduling for sugarcane using a vadose zone flow and transport model. Agricultural Water Management 98:1431-1440.

Tafteh, A., and A. R. Sepaskhah (2012) Application of HYDRUS-1D model for simulating water and nitrate leaching from continuous and alternate furrow irrigated rapeseed and maize fields. Agricultural Water Management 113:19-29.

Weng-Zhi, Z., H. Jie -shang, W. Jing-wei, X. Chi (2013) Modeling soil salt and nitrogen transport under different fertigation practices with Hydrus-1D. Advance Journal of Food Science and Technology 5:592-599.

Appendix B – CDFA FREP Proposal

B-I. Cover Page

1. Project Title

Evaluation of the Multiple Benefits of Nitrogen Management Practices in Walnuts

2. Project Leaders

Parry Klassen: Project Director/Principle Investigator (PI), Coalition for Urban Rural Environmental Stewardship (CURES), 1480 Drew Ave. #130, Davis, CA 95618, 559-288-8125, pklassen@unwiredbb.com

Allan Fulton: Co-PI, University of California Cooperative Extension Division of Agriculture and Natural Resources Tehama County, 1754 Walnut St., Red Bluff, CA 96080, 530-527-3101, aefulton@ucanr.edu

3. Project Cooperators

Alan Reynolds: Board Chairman, East San Joaquin Water Quality Coalition, 1201 L Street, Modesto, CA, 209-394-6200, alan.reynolds@ejgallo.com

Joseph McGahan: Executive Director, Westside San Joaquin River Watershed Coalition, 559-582-9237, jmcgahan@summerseng.com

Bruce Houdesheldt: Executive Director, Sacramento Valley Water Quality Coalition, 916-442-8333, bruceh@norcalwater.org

Michael Wackman: Executive Director, San Joaquin County & Delta Water Quality Coalition, 916-684-9359, michaelkw@msn.com

4. Supporters

Parry Klassen: Chair, Management Practices Evaluation Program Group Coordinating Committee (MPEP GCC), 1201 L Street, Modesto, CA, 559-288-8125, pklassen@unwiredbb.com

Doug Parker: Director, California Institute for Water Resources, University of California Agricultural and Natural Resources, 1111 Franklin St., 10th Floor, Oakland, CA 94607, 510-987-9124, doug.parker@ucop.edu

Adam Laputz: Assistant Executive Officer, Central Valley Regional Water Quality Control Board, 11020 Sun Center Drive, #200, Rancho Cordova, CA 95670, 916-464-4726, Adam.Laputz@waterboards.ca.gov

Renee Pinel: President and CEO, Western Plant Health Association, 4460 Duckhorn Drive, Suite A, Sacramento, CA, 95834, 916-574-9744, reneep@healthyplants.org

David Ramos, Ph.D.: Production & Post-Harvest Research Consultant, California Walnut Commission, 101 Parkshore Dr. Ste. 250, Folsom CA 95630, 916-932-7070, deramos@ucdavis.edu

5. CDFA Funding Request Amount/Other Funding

Funding requested from California Department of Food and Agriculture, Fertilizer Research and Education Program: $109,381.20 (2015/2016), $81,362.30 (2017), and $34,250.40 (2018) for a total of **$224,993.90**. Central Valley Irrigated Lands Regulatory Program Third Party Groups (CV Coalitions) have pledged funds for this project however due to the timing of this proposal an exact amount could not be determined at this time. It is anticipated that each Coalition will be able to contribute $5,000 ($5,000 in 2016 and $5,000 in 2017) per year as well as in-kind services in the form of technical review and member outreach. The pledge needs to be confirmed by each respective board of directors in March 2015.

Alan Reynolds: Board Chairman, East San Joaquin Water Quality Coalition, 1201 L Street, Modesto, CA, 209-394-6200, alan.reynolds@ejgallo.com; **ESJWQC Contribution: $10,000**

Joseph McGahan: Executive Director, Westside San Joaquin River Watershed Coalition, 559-582-9237, jmcgahan@summerseng.com; **WSJRWC Contribution: $10,000**

Bruce Houdesheldt: Executive Director, Sacramento Valley Water Quality Coalition, 916-442-8333, bruceh@norcalwater.org; **SVWQC Contribution: $10,000**

Michael Wackman: Executive Director, San Joaquin County & Delta Water Quality Coalition, 916-684-9359, michaelkw@msn.com; **SJCDWQC Contribution: $10,000**

6. Agreement Manager

Parry Klassen: Coalition for Urban Rural Environmental Stewardship, 559-288-8125, pklassen@unwiredbb.com, 1480 Drew Ave. #130, Davis, CA 95618

B-II. Executive Summary

1. Problem

Nitrate is a major contaminant in Central Valley groundwater and elevated levels are attributed primarily to leaching of nitrogen fertilizers past the root zone. Growers who belong to Central Valley Water Quality Coalitions (CV Coalitions) are under new requirements per the Irrigated Lands Regulatory Program to keep "on farm" a Nitrogen Management Plan (NMP) to track nitrogen fertilizer applications. A key component of the NMP is reporting nitrogen consumption during the growing season with the assumption that the remaining nitrogen is lost to groundwater. Determining crop consumption is one of several requirements of the Management Practices Evaluation Program (MPEP) that five CV Coalitions are cooperatively implementing (East San Joaquin Water Quality Coalition, Westside San Joaquin River Watershed Coalition; San Joaquin County and Delta Water Quality Coalition; Sacramento Valley Water Quality Coalition; Westlands Water Quality Coalition). The MPEP has specific objectives including identifying management practices that are protective of groundwater quality, determining whether newly implemented management practices are improving or may result in improving groundwater quality, developing an estimate of the effect of Member's discharge of nitrate on groundwater quality and utilizing the results to determine whether practices need to be improved. There are data gaps in understanding the effectiveness of management practices on reducing the amount of nitrate transported through the root zone of walnuts. This project will document the amount of nitrogen applied and the movement and distribution of nitrate from the point of application through the root zone in 2 walnut orchards. This project will evaluate the movement of nitrogen through the root zone during rain and irrigation events over a two year period.

2. Objectives, Approach, and Evaluation

<u>Objective 1</u>: Identify the management practices being implemented to reduce the amount of nitrogen moving through the root zone for Orchard 1 and Orchard 2.

Approach: Fields will be identified with the assistance of the cooperating CV Coalitions and the California Walnut Commission. Management practices implemented by growers will include split fertilizer applications (based crop load and UC/industry expertise on optimal timing), and testing of soils/irrigation water/petiole-leaf to better understand crop nitrogen need and the amount of nitrogen and nutrients needed for optimal production. In addition, both orchards will use microsprinkler irrigation as a management practice to reduce the potential for leaching. Measurements will be collected over two years (two storm seasons and two irrigation seasons). Note: exact management practices beyond those listed will be determined once cooperator(s) have been identified. Two years will be necessary to ensure that the nitrogen measurements are repeatable from year to year and the study includes annual variability in weather and pest pressures. The BMPs will be implemented for at least two years allowing for changes in yields as a result of the BMPs and full evaluation of leaching potential.

Evaluation: Management practices for nitrogen fertilizer applications and irrigation timing will be identified for both fields prior to the implementation of the study. Throughout the two year study, practices performed by the grower such as nitrogen applications and irrigation events will be recorded. Total yield and root zone nitrate results will be compared over the two years to account for the effect of the implemented BMPs on the amount of nitrate leaching and changes (if any) in yield.

<u>Objective 2:</u> Determine the amount and timing of nitrogen moving through the root zone.

Approach: The study will be conducted in 5 acre plots in two different fields. The fields will be located within the cooperating CV Coalition boundaries (Madera County north to Shasta County). Each field will be sampled in the winter following adequate rain to saturate soils and throughout two irrigation seasons. Samples will be collected from:

- Lysimeters to evaluate the amount of nitrogen in the water moving through the root zone;
- Soil to evaluate the amount of nitrogen in the soil;
- Irrigation water to evaluate the amount of nitrogen in water used during irrigation that is in addition to fertilizer applications;
- Crop tissue at appropriate time intervals including harvest.

Soil permeability will be measured with a constant head permeameter during each of the three time periods (sets) during both years of the study. Permeability will be measured at the same time that soil samples are collected. Permeability measurements will be used to assess the heterogeneity of the field with respect to soil hydraulic conductivity. Tissue samples, including the roots (where possible) will be collected at randomly selected locations in each field throughout the growing season. Samples will be collected from the lysimeters after winter rain events to better determine the movement of residual nitrogen in the soil as a result of rain.

Evaluation*:* Data collected from the field studies will be recorded in an electronic database, analyzed and summarized in interim and final reports. The reports will evaluate nitrate leaching in the two fields. Results will be placed in the context of previous studies on nitrogen leaching in walnuts.

<u>Objective 3</u>: **Identify the multiple benefits of nitrogen management practices implemented in Orchard 1 and Orchard 2 including potential cost savings (reduced water costs, reduced amount of money spent on fertilizer) and groundwater protection (reduction in the amount of nitrogen that is moving through the root zone).**

Approach: Costs for implementing the practices will be quantified for each individual management practice. Elements to be evaluated include: cost of water, cost of fertilizer applications, labor costs, and additional costs for practices such leaf, water and soil analysis. The benefit of protecting groundwater will be estimated by using the information obtained regarding the movement of nitrogen through the root zone.

Evaluation: The costs of implementing identified management practices will be quantified and the benefit of protecting groundwater will be estimated. The evaluation of these benefits will be included with outreach materials to encourage growers to implement similar practices.

<u>Objective 4:</u> Determine if additional practices could be implemented to further reduce the amount of nitrogen moving past the root zone.

Approach: Once the amount and timing of nitrogen moving through the root zone is determined, the range of management options can be evaluated to determine if it is possible to reduce nitrogen moving past the root zone. The range of management options will be identified with the assistance of Allan Fulton of UC Davis Cooperative Extension (Co-Principle Investigator) and Dr. David Ramos of the California Walnut Commission.

Evaluation: An analysis of management options will be performed after the two year study with the assistance of the California Walnut Commission, crop specialists with UCANR, CDFA and other experts in walnut production and included in the final report.

Objective 5: Disseminate results to growers of walnuts.

Approach: Walnut growers will be provided the results of this study through the Outreach component of this project. Field Days will be conducted during the study time period to demonstrate the management practices implemented; these will be scheduled once the project is approved for funding. In addition, at the conclusion of this project and summary write up will be provided to the CV Coalitions for use in coalition member outreach.

Evaluation: During the Field Days, the participants will be surveyed to determine the effectiveness of the demonstration. The number and types of outreach materials will be recorded.

3. Audience

Initially walnut growers and their crop advisors, water quality coalitions, UC Extension Farm Advisors, State and Regional Water Quality Control Boards and the FREP program are the target audience for knowledge gained from this project. Eventually the results of this project and other CURES' related projects will also be relevant and beneficial to growers with many annual crops in California's Central Valley. The information will help guide the selection of practices used by members of CV Coalitions who are required to use nitrate management practices known to minimize contamination of groundwater with nitrates and be compliant with groundwater protection regulations. Study results will help fill knowledge gaps and identify benefits to growers who implement multiple nitrogen management practices including better understanding of the efficacy of these practices in protecting groundwater resources while maintaining expected crop yield potential and quantifying cost savings.

B-III. Justification

4. Problem

Elevated levels of nitrate present in groundwater in Central Valley locations are being attributed, in part, to inputs from farming practices. The Central Valley Water Board estimates that approximately three million acres of irrigated lands overlay groundwater aquifers that have high levels of nitrogen or are vulnerable to nitrate contamination. In the Central Valley, approximately 33,000 landowners/operators are affected by the new ILRP requirements to implement practices to protect groundwater. Similar groundwater issues are problematic in other regions of California as well. The objective of the NMP and the MPEP is to better manage and understand the amount of nitrate that is leached to groundwater when Best Management Practices (BMPs) are implemented while also assuring that these processes are indeed effective. This project will document the uptake of nitrate fertilizer by the walnut crop and the movement and distribution of nitrate through the root zone in a walnut orchard. The resulting data will assist FREP, growers, water quality coalitions, Western Plant Health Association (WPHA), Certified Crop Advisors, UC Extension Farm Advisors, and the state and regional Water Boards in understanding nitrogen behavior, movement and distribution as fertilizer moves through the soil. Additionally, the results of this study can be used in the other agricultural areas of California where groundwater contamination with nitrate is of critical concern.

5. FREP Mission and Research Priorities

This study supports FREP's goals of filling the information gap in the understanding nitrogen behavior, movement and distribution as it moves from the point of application through the soil and past the root zone. The study results will assist with the evaluation and advancement of the environmentally safe and agronomically sound use of nitrogen fertilizers. The data from this project will also be useful, in combination with other research, to support FREP's goal of assessing the quantity of nitrates from nitrogen fertilizers accumulating in groundwater.

6. Impact

The research will provide growers and crop advisors with information needed to quantify the loss of nitrate through the root zone for selected management practices. This information can be used by growers to adjust their management practices and reduce the amount of nitrate lost to groundwater. Additionally, the information generated by this project will help growers optimize their nitrate applications and save money in their farming operation. The BMP recommendations will be vital to walnut growers in the Central Valley, who are an important part of the approximately 33,000 landowners/operators who farm nearly 7 million acres of land and are impacted by the new ILRP requirements to improve nitrogen and irrigation practices to minimize nitrate discharges to ground and surface water.

In addition, the research techniques and protocols developed during this study will be the demonstration to the Regional Board that this study design can be replicated in other locations and with other crops to evaluate the efficacy of management practices. The information generated by this project will be critical in allowing the CV Coalitions to meet the compliance measures outlined in their Waste Discharge Requirements.

7. Long-Term Solutions

Over the long-term, implementation of the nitrate BMPs evaluated by this project will contribute to measureable reductions in nitrate discharges to groundwater, and thereby contribute to the restoration of groundwater drinking water resources. The restoration of groundwater will reduce the regulatory compliance costs of all users of water. In addition, evaluating nitrate BMPs can reduce the economic cost of over fertilization providing growers with a potentially significant cost savings within their operation. Additionally, the reduction of impacts to groundwater reduces treatment costs associated with domestic supply wells which can allow expanded use of lower cost groundwater for domestic uses.

8. Related Research

Research: The management of fertilizer applications can be done only with knowledge of the 4 R's (right time, right place, right source, and right rate) for each crop. Very little is known about the 4 R's for most of the crops grown in the Central Valley. Studies are just beginning to be performed to develop nutrient budgets and optimum fertilizer management in walnuts. DeJong et al. (2014[3]) determined that depending on variety and location, approximately 25 – 30 lbs N/ton (1% - 1.5%) is removed in harvested biomass (nuts and hulls) in walnut orchards. However, DeJong et al. found that there was more variability between sites across cultivars than between cultivars. Soil nutrient loss varied spatially from sandy loam to silt loam to clay loam. Early analytical results indicated that soil variability was high even within a small portion of an orchard but initial results showed leaching of nitrate as early as late July and increasing towards the end of the season with heavy precipitation events. Leaching did not appear to occur during the growing season due to the limited movement of water below the root zone.

There is little other research being conducted although there is some work on carrots (Allaire-Leung et al. 2001[4])

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[3] DeJong, T, K. Pope, P. Brown, B. Lampinen, J. Hopmans, A. Fulton, R. Buchner, and J. Grant. 2014. Development of a nutrient budget approach and optimization of fertilizer management in walnut. Walnut Research Reports, California Walnut Board

[4] Allaire-Leung, S. E., L. Wu, J. P. Mitchell, and B. L. Sanden. 2001. Nitrate leaching and soil nitrate content as affected by irrigation uniformity in a carrot field. Agricultural Water Management 48:37-50.

and some recent work has been performed using tomatoes (e.g., Hartz and Hanson 2009[5], Hartz and Bottoms 2009[6]). A majority of the research involves evaluating practices that optimize the use of applied N. Hartz and Hanson (2009) reported that conventionally-irrigated tomatoes need 100 – 150 lbs of nitrogen per acre because there is an additional substantial contribution from residual soil NO_3 and from the mineralization of organic N in the soil during the growing season.

Hartz and Hanson (2009) and Hartz and Bottoms (2009) reported:

- Early season NO_3-N analysis of soils can guide application rates during the growing season,
- Nutrient uptake (including P and K in addition to N) is slow until fruit set begins and then accelerates significantly,
- The majority of the accumulation of N occurs between flowering and fruit maturity,
- Nutrient uptake slows significantly in the last weeks before harvest and it is unnecessary to apply fertilizer during this period (right time),
- Several smaller fertigation events during the period of rapid uptake are optimal (right rate and right place),
- Leaf N analysis early in the growing season is the best measure of nitrogen status and can provide an indication of the nitrogen sufficiency status of the crop.

Although Hartz and Hanson (2009) and Hartz and Bottoms (2009) reported that leaching of N from drip irrigated tomatoes should be low during the season, estimates of in-season leaching are not available and it is not clear how much NO_3 may be lost from the root zone during the winter season.

Dr. Patrick Brown and his colleagues have developed a significant amount of information about the 4 R's in the context of minimizing leaching of nitrate to groundwater in almonds and pistachios (e.g. Hopmans et al. 2010[7]). Dr. Brown and Mr. Fulton are currently involved in research projects with walnuts that are addressing the loss of nitrate through the root zone although those projects are in their early stages and no results are widely available. Although permanent crops are very different from annual crops, there does appear to be commonality in the results of research on N use in annual crops and almonds including:

- The concentration of nitrate in the fertigation system during a fertigation event influences the efficiency with which N is used. Root nitrogen uptake is also influenced by previous nitrate inputs to the system and suggests that providing small amounts of nitrate over time are more efficiently used compared to larger applications (right rate).
- The majority of the accumulation of N occurs between flowering and fruit maturity,
- Nutrient uptake slows significantly in the last weeks before harvest and it is unnecessary to apply fertilizer during this period (right time),
- Leaf N analysis early in the growing season is the best measure of nutrient status and can provide an indication of the nutrient sufficiency status of the crop.

In addition to the research cited above, CURES has conducted research in walnuts in an orchard near Stockton.

[5] Hartz, T. and B. Hanson. 2009. Drip irrigation and fertigation management of processing tomato. University of California Vegetable Research and Information Center. 11 pgs.
[6] Hartz, T. K. and T. G. Bottoms. 2009. Nitrogen requirements of drip-irrigated processing tomatoes. HortScience 44:1988-1993.
[7] Hopmans, J. W., M. M. Kandelous, A. Olivos, B. R. Hanson, and P. Brown. 2010. Optimization of water use and nitrate use for almonds under micro-irrigation. Almond Industry Conference, Modesto, CA.

Although one of the major aspects of that research was to identify a reliable method of sampling nitrate below the root zone, additional information was collected on the effectiveness of a "right rate" management practice. Briefly, thirty suction lysimeters were placed in an orchard and samples were collected after each irrigation event throughout the irrigation season. Sources of nitrate included irrigation water, nitrate applied during fertigation, residual soil NO_3-N, and mineralized N. The orchard experienced some leaching of nitrate below the root zone as measured by the concentration of nitrate in water collected in lysimeters located below the roots (CURES report to CDFA in preparation).

Outreach: For over 15 years, CURES in collaboration with academic, commodity, professional, regulatory and non-profit organizations, has been instrumental in testing the efficacy of BMPs for improving water quality and facilitating widespread implementation and adoption of BMPs and Integrated Pest Management (IPM). CURES has produced numerous publications on BMPs for reducing off-site movement of sediments, nutrients and pesticides to surface water, irrigation management practices and practices for supporting healthy populations of pollinators, and assembled region-specific collections of these technical bulletins in binders entitled "BMP Handbook," with distribution to approximately 7,500 growers, PCAs, and agricultural organizations in the Central Valley. The BMP publications and the results of water quality related BMP studies are posted on CURES website: www.curesworks.org. Additionally, by utilizing a group of experts participating in the MPEP effort, the contribution will be from a broader base and in the process educate those in the agricultural community who are less likely to be knowledgeable about nitrogen research and options.

CURES project leader, Parry Klassen, has extensive experience in production agriculture. Mr. Klassen also serves as Executive Director of the East San Joaquin Water Quality Coalition. This organization represents more than 3,900 landowners in Madera, Merced and Stanislaus counties under the Irrigated Lands Regulatory Program. Among other responsibilities, Klassen manages the grower outreach and education programs and also actively participates in CV-SALTS and the MPEP effort on behalf of the East San Joaquin Water Quality Coalition.

Bill Jones, CURES' field specialist, has more than 30 years of professional experience in crop nutrition, irrigation water chemistry, and soil fertility management in a variety of crops in California. His recent projects include pre-plant assessments of soil fertility, irrigation water, selection and application of organic amendments, and plant nutrition management on farms in Tulare, Kern, and Fresno Counties.

Allan Fulton, the project's co-PI has more than fifteen years of experience working with orchard irrigation and soil management including evaluating off-site water quality impacts. He has worked with orchard managers on integrated water management concepts and groundwater hydrology.

MLJ-LLC and its principal Dr. Michael L. Johnson and field manager Matthew Zane, bring over 25 years of experience in basic and applied science to problems involving water quality. MLJ-LLC employs several environmental scientists that have experience with similar studies conducted in the Salinas Valley using romaine lettuce. MLJ-LLC staff are available to work on this project at all times as needed and necessary.

9. Contribution to Knowledge Base

Some information is available on the management of nitrate in walnuts with the assumption that proper nitrogen applications (fertigation), use of subsurface drip irrigation, and standard yields results in minimal or no leaching of nitrate to groundwater. However, this has yet to be demonstrated for walnuts and there is little known about potential leaching of nitrate during the fallow winter season. This project will confirm the conclusions made in previous studies of walnut nutrient management and provide growers with the information necessary to come into compliance with their WDRs. In addition, this study will allow the Management Practices Evaluation Program Group Coordinating Committee (MPEP GCC) to develop a template study design that can be used across several orchard crops in the Central Valley.

10. Grower Use

The nitrogen practices implemented during the study will be considered characteristic of what the "early adopters" of that crop are currently using. Most of the practices are already being used widely but not often simultaneously in a field. For instance, drip/microirrigation is widely used in the Central Valley. But drip irrigation, tissue/leaf sampling, split applications of nitrogen, pre- and post-crop soil testing, soil moisture sensors, and other newer practices, may not all be used at once in a single orchard. This project is intended to show that when all the "best" practices for the cropping conditions are used, nitrate movement to groundwater can be minimized/eliminated and, presumably, increased production will cover the cost. Once data are developed on the effectiveness of these practices when used in combination, growers will be motivated to adopt the measures by pressure currently exerted by regulatory agencies to protect groundwater resources. Information will also be provided to growers on the costs of the practices and potential yield or quality benefits that might be expected by their adoption.

B-IV. Objectives

Objective 1: Identify the management practices being implemented to reduce the amount of nitrogen moving through the root zone for Orchard 1 and Orchard 2.

Objective 2: Determine the amount and timing of nitrogen moving through the root zone.

Objective 3: Identify the multiple benefits of nitrogen management practices implemented in Orchard 1 and Orchard 2 including potential cost savings (reduce water costs, reduce amount of money spent on fertilizer) and groundwater protection (reductions in the amount of nitrogen that is moving through the root zone).

Objective 4: Determine if additional practices that could be implemented in order to further reduce the amount of nitrogen moving through the root zone.

Objective 5: Disseminate results to growers of walnuts.

B-V. Work Plans and Methods (for multi-year projects, include a work plan for each year)

11. Work Plan

Task 1 – Project Management: Project management will occur throughout the duration of the project to ensure that Tasks 2 – 6 are being completed on time and on budget. This task will ensure that **Objectives 1-5** are met. Project Management will include coordination of the study team personnel including the Co-PI, Project Advisor, Project Cooperators, Project Supporters and the Subcontractor MLJ-LLC. **Task Products** include progress reports and invoices submitted in a timely manner to CDFA. This task will continue throughout the project term.

Task 2 – Grower Identification: The cooperator grower will be identified based on availability and willingness to participate with the assistance of the Project Team in order to meet **Objective 1**. **Task Products** include the recording of management practices implemented to increase the efficiency of nitrogen use including application timing and irrigations. This task will occur prior to the implementation of sampling and during both years of the study. Grower identification will be completed 3 months after project initiation (October 2015).

<u>Task 3 – Study Design</u>: The Study Design will be refined once the cooperator growers and the fields are identified. The **Task Product** is the study design which will include mapping of the fields, review of soil map data to ensure comparability between fields, determination of the grid cells for the sampling and scheduling of sampling. This will be included in the Summary Report. The Study Design is essential for meeting **Objective 2** in combination with Task 4 – Sampling. The Study Design will be agreed upon by the Project Team prior to initiation of sampling of a rain event which is scheduled to occur between November 2015 and March 2016.

<u>Task 4 – Sampling</u>: Sampling will include soil, pore water, irrigation water and plant tissue N. The study will also include permeability measurements in order to meet **Objective 2.** Sampling will occur after a rain event each year (November – March) and approximately 4 irrigation events (this may include a pre-irrigation event). The Sampling Design (Task 3) will refine the sampling schedule in order to meet **Objective 2**. **Task Products** include sample collection and receipt of results from the laboratory/field sampling.

<u>Task 5 – Data Management</u>: Results obtained from sampling (both laboratory and field results) as well as management practice information (details regarding timing and rates of applications) will be recorded in an electronic database. Data will be analyzed to evaluate differences in nitrate leaching between orchards **(Objective 2)** and estimate costs for implementing practices **(Objective 3). Task Products** include an electronic database of results to be used for data analysis in the Summary Report. Data Management will begin with the first sample collection (2015/2016) and end with the draft Summary Report (2018).

<u>Task 6 – Summary Report</u>: The Summary Report will include the identification of management practices, sample design, analysis of results, evaluation of nitrate leaching between fields, a cost analysis of BMP implementation, identification of additional practices that could be implemented, and documentation of outreach efforts **(Objectives 1-5). Task Products** include a draft Summary Report that will be disseminated to the Project Team for comments/edits. A final Summary Report will incorporate comments from the Project Team and submitted to CDFA. Information from the Summary Report will be utilized in outreach materials.

<u>Task 7 –Outreach</u>: Outreach will include Field Day demonstrations and dissemination of results to growers and CV Coalitions. Field Days will be conducted to demonstrate the management practices being implemented and the results from the Summary Report will be distributed to the MPEP GCC and CV Coalitions to meet **Objective 5. Task Products** include outreach materials summarizing the conclusions of the study.

TABLE 3. WORK PLAN TASKS AND SUBTASKS BY YEAR.

Task / Subtask	Task Products	7/2015 –	1/2016 – 12/201	1/2017 – 12/201	1/2018 –	Completion Dates
1. Project Management	Progress Reports, Invoices	x	x	X	X	June 2018
2. Grower Identification	Agreement with grower List of management practices	x				October 2015
3. Study Design *3.1. Assess Field Comparability* *3.2. Map Sample Locations* *3.3. Determine Sampling Locations*	Study Design	x				December 2015
4. Sampling *4.1. Preparation/Cleanup* *4.2. Equipment Installation* *4.3. Sample Collection*	Sample Collection /Analysis	x	x	X		January 2018

Task / Subtask	Task Products	7/2015 –	1/2016 – 12/201	1/2017 – 12/201	1/2018 –	Completion Dates
5. Data Management / Analysis *5.1. Field Data Entry* *5.2. Laboratory Data Review / Entry* *5.3. BMP Cost Estimates* *5.4. Database Management*	Electronic database	x	x	X	X	March 2018
6. Summary Report *6.1. Draft Report* *6.2. Final Report*	Draft Report Final Report			X	x x	March 2018 June 2018
7. Outreach *7.1. Conclusion Summaries for Outreach* *7.2. Field Days*	Outreach Materials		x	X	X	June 2018

12. Methods

Field Characteristics: Two orchards with similar management practices and irrigation systems will be selected in a geographically similar location. Both orchards will be adequately characterized to ensure they meet the necessary parameters of the study. Characterization will include soils, irrigation timing and volume, and irrigation system design. A 5 acre study plot will be selected within each of the two orchards and 15 grid cells will be established in each plot. Field heterogeneity will be addressed by first consulting NRCS soil maps and attempting to locate 5-acre study plots that lie within a single soil type. Depending on the parameter, between 5 and 15 measurements will be collected. For lysimeters, 15 samples will be collected from each plot during each irrigation event. Further analysis of heterogeneity will be done using statistical analysis on a combination of soil nitrate data and field hydraulic conductivity data developed from permeability measurements. Both irrigation efficiency and irrigation distribution uniformity are important factors determining the spatial variability in the rate at which nitrate moves through the soil. The location of each of the 5 acre study plots will be selected to address these factors. Irrigation timing and volume data at both sites will be gathered using a pulse output water meter and data logger. Soil permeability will be calculated using measurements obtained from a compact constant head permeameter. Soil samples and pore water samples will be collected and analyzed for nitrate to quantify movement through the root zone. Tissue samples will be collected to calculate the amount of nitrogen in various plant tissues. Gross yield data and nitrate results from tissue samples collected at harvest will be used to quantify the amount of nitrate removed at harvest.

Permeability: Each year 10 measurements of saturated hydraulic conductivity (K_{sat}) will be made on each of the 5 acre plots using a compact constant head permeameter (Amoozemeter). Field saturated hydraulic conductivity (K_{sat}) will be measured within 7 randomly selected grid cells at a well depth of 24 inches and a constant head depth of 12 inches.

Soil N: Three sets of 15 soil samples will be collected and analyzed for N each year. The first soil collection will occur prior to any pre-irrigation. A second soil collection will occur approximately half way through the crop cycle. The third set will be collected immediately after the harvest. Soil will be collected from five randomly chosen locations. Using a spoil probe, soil from a single hole will be collected from three depth intervals; 0-24 inches, 24-48 inches and 48-72 inches. Each set of cuttings will be homogenized and transferred to a 4-oz glass container.

The samples will be submitted to the laboratory and analyzed for nitrate as N (EPA 300.0) and percent solids (SM 2540G). N mineralization potential will be measure by Solvita soil respiration or water extractable organic C and N. Mineralization potential is necessary to understand the conversion of organic N to NO_3 which then becomes an available source of nitrate for the crop. Samples will be collected at the same time as samples are collected for NO_3 analysis of soil.

Irrigation Water N: Samples of irrigation water will be collected and analyzed for nitrate. Three samples will be collected during the growing season; at the time of initial irrigation, mid-season, and at the time of the final irrigation.

Pore Water N: Suction lysimeters will be used to quantify N concentrations past the root zone. Suction lysimeters will be installed in each grid cell at a depth of 42-44 inches. For each sampling event, a manual suction of 60-75 PSI will be pulled on each lysimeter using a hand pump. Using a syringe, samples will be collected between 16 and 24 hours after suction has been pulled. Samples will be delivered to the laboratory within 24 hours to be analyzed for nitrate as N (EPA 300.0). Samples will be collected during a minimum of three irrigation events and will capture at least one fertigation event. Funding provided by cooperators will be used to sample and capture the remaining irrigation/fertigation events.

Plant Tissue N: Two sets of 10 tissue samples will be collected and analyzed for N content and percent moisture each year. The first collection will occur approximately halfway between planting and harvest. The second set will be collected the day prior to harvest. A tree from 10 randomly chosen grid cells within the 5 acre study area will be selected for tissue sampling. Leaf and fruit samples will be collected from each tree. In addition, an attempt will be made to collect root and woody tissue samples from each of the trees. If this is not feasible, previous studies on N content of roots and woody tissue for walnut trees will be evaluated and incorporated into the study.

Data Analysis: Measured parameters (e.g. concentration of nitrate in leachate, plant tissue N, soil residual N, mineralization rate) will be compared between fields using standard statistical procedures such as repeated measures ANOVA. Analyses such as plot characterization will be done with multivariate methods such as Principal Components Analysis. The relationship between the concentration of nitrate leaching past the root zone and other variables such as the amount of nitrate in irrigation source water, fertigation rate will be analyzed graphically because the sample size of 2 (or 3 if possible) precludes statistical analyses. Spatial variability in permeability the concentration of NO_3 in soils and leachate collected by lysimeters will be analyzed using standard spatial statistics.

13. Experimental Site

The study area will consist of two 5 acre blocks; each block will be located in a different walnut orchard located near Chico, CA. The orchards will be selected based on similar management and irrigation practices and both will be irrigated via surface drip. CURES is currently working with UCCE and the California Walnut Commission to identify cooperators. Identification of orchards in which to conduct the study is the first objective of the study.

B-VI. Project Management, Evaluation and Outreach

14. Management

This project, as with the other projects for which CURES is seeking FREP funding, will be managed by a specific project team described below along with oversight by the MPEP GCC and the MPEP Technical Committee (members listed below). CURES is using this project as the pilot for additional studies to be performed over the next several years and these planned studies will also be managed by the MPEP GCC. The MPEP GCC has responsibility to perform studies to demonstrate that management practices used in irrigated crops grown in the Central Valley are protective of groundwater resources. While the project team will have responsibility for the activities and deliverables of this project, the MPEP GCC and its Technical Committee will provide feedback, advice and ongoing guidance to this project. It is expected that the project will be managed using a process that after the first year is completed, may result in adjustments in the study design to ensure that the most accurate and useful information is developed. Any changes to this project would be reviewed and approved by FREP contract managers before they are undertaken.

The project director and principal investigator, Parry Klassen, is Executive Director of the Coalition for Urban Rural Environmental Stewardship (CURES), a non-profit, 501c3 organization. Mr. Klassen has a B.S. in Agricultural Communication from California State University, Fresno, and is a commercial fruit grower in Fresno County. Mr. Klassen has been closely involved with the formation of Central Valley watershed coalitions since 2002 with CURES and as executive director of the East San Joaquin Water Quality Coalition. CURES, under the management of Mr. Klassen, has worked in collaboration with academic, commodity, professional, regulatory and non-profit organizations and has been instrumental in testing the efficacy of BMPs for improving water quality and facilitating widespread implementation and adoption of BMPs and IPM. Mr. Klassen and CURES staff will manage this project, facilitate communication and collaboration among the cooperating entities through conference calls and team meetings, ensure that the study goals and objectives are being addressed throughout the project, oversee the field research, deliver outreach presentations, work with the grower cooperator to assist with management practice implementation and study logistics coordination, and gather and compile all supporting materials from collaborators and subcontractors to submit reports, invoices and deliverables to the FREP Grant Manager on time and on budget.

The project Co-PI, Allan Fulton, earned his Master's in Soil and Irrigation Science from Colorado State University, Fort Collins in 1986. Mr. Fulton has more than fifteen years of experience supporting the California walnut industry through applied research and education programs as an Extension Specialist with the University of California. Mr. Fulton will provide oversight and technical support for the research project.

The MPEP GCC is made up of five Central Valley water quality coalitions and encompasses more than 5 million acres of irrigated cropland. The participating coalitions include the East San Joaquin Water Quality Coalition, Westside San Joaquin River Watershed Coalition, the San Joaquin County and Delta Water Quality Coalition and the Sacramento Valley Water Quality Coalition who are all cooperators of this study. The MPEP GCC includes the Executive Directors of each Coalition, a member of each Coalition's Board of Directors, and an alternate for each member of the respective Board of Directors. In 2014, the MPEP GCC formed a Technical Committee to provide oversight and direction to all its crop research projects. The committee is made up of the following individuals:

- Dr. Patrick Brown, UC Davis Department of Plant Sciences
- Dan Munk, UCCE Farm Advisor
- Allen Fulton, UCCE Irrigation and Water Resources Advisor
- Doug Parker, Director, California Institute for Water Resources, UC Agricultural and Natural Resources
- Dr. Rob Mikkelsen, International Plant Nutrition Institute
- Dr. Tim Hartz, UCCE Vegetable Crops Specialist, Department of Vegetable Crops

- Lowell Zelinski, Precision Ag Consulting
- Dr. Gabriele Ludwig, Almond Board of California
- Charles Rivara, California Tomato Research Institute
- Mark Cady, CA Department of Food and Agriculture
- Barzin Moradi, CA Department of Food and Agriculture

The MPEP GCC is working with its Technical Committee to develop a conceptual study design for all its studies performed under the MPEP, including the proposed project. The MPEP GCC contracted with CURES to serve as MPEP Administrator. The MPEP GCC will collaborate with CURES to provide project outreach, and has pledged in-kind funding for this project.

Michael L. Johnson will be responsible for conducting the research guided by the Co-PIs and the MPEP Technical Committee. Dr. Johnson is the President and Managing Partner of MLJ-LLC and brings over 25 years of extensive experience to this project. Dr. Johnson spent 26 years as an academic scientist, first at the University of Kansas and the last 18 years were spent as a research scientist at UC Davis. Dr. Johnson has considerable experience conducting research including both field and laboratory studies. Dr. Johnson retired from UC Davis Center for Watershed Sciences in 2010.

15. Evaluation

This study does not include new technologies and barriers to adoption are not anticipated.

Throughout the study, practices performed by the grower such as nitrogen applications and irrigation events will be recorded. Data collected from the field studies analyzed and summarized in interim and final reports. Study results will be compared to previously performed studies on the crop. The costs of implementing identified management practices will be quantified and the benefit of protecting groundwater will be estimated. The evaluation of these benefits will be included with outreach materials to encourage growers to implement similar practices. An analysis of management options will be performed after the two year study with the assistance of the California Walnut Commission, crop specialists with UCCE, CDFA and other experts in walnut production and included in the final report. During the Field Days, the participants will be surveyed to determine the effectiveness of the demonstration. The number and types of outreach materials will be recorded.

16. Outreach

CURES, on behalf of the MPEP GCC, will organize multiple outreach efforts throughout and following the two year field trial. The MPEP GCC will promote Field Days in which growers and interested parties are invited to the study site to view the project in process. Once the data gathered during the study are analyzed, CURES will compile a PowerPoint presentation and organize meetings for Coalition members who grow walnuts. These meetings will be held in all of the participating Coalition regions. In addition, each of the participating Coalitions will be provided outreach materials (e.g. presentations, summary results) to include in their Annual Member Meetings. A summary of the project and results will be compiled into a written publication that will be distributed to growers, commodity groups, California crop advisors, and other interested parties. Specific dates for Field Days will be set based on progress of the studies, and the availability of growers and participating CV Coalitions. CURES will update FREP regarding meeting dates as they are set.

B-VII. Budget Narrative

The budget attached in the budget template is based on funds being available as of July 2015. The funds included in the attached budget template include 2015 funds in the 2016 estimate.

a. Personnel Expenses

CURES staff are listed below including the number of hours estimated to work on the study project per year. The Annual Total includes all wages and benefits. CURES staff will manage contracts, invoicing and progress reports and ensure that subcontractors remain on schedule and within budget.

Personnel, Title (% full time)	*Hrs / Yr*	*Wage/ Hour*	*10% Benefits*	*10% Overhead*	*Wage/ Hour*	*Annual Total*
Parry Klassen, Project Director/PI (2%)	60	$130.00	$13.00	$13.00	$156.00	$9,360.00
William Jones, Project Manager (4%)	60	$110.00	$11.00	$11.00	$132.00	$7,920.00
Clint Phelps, Assistant PM (2%)	60	$50.00	$5.00	$5.00	$60.00	$3,600.00
Tamara Watson, Contracts Manager (1%)	24	$60.00	$6.00	$6.00	$72.00	$1,728.00
Kara Stuart, Administrative Assistant (3%)	120	$35.00	$3.50	$3.50	$42.00	$5,040.00
TBD, Bookkeeper (2%)	36	$30.00	$3.00	$3.00	$36.00	$1,296.00

b. Operating Expenses

Supplies: $300 over the duration of the project is included for office-related expenses including teleconferencing, copies, and document sharing website.

Equipment: All equipment needed for this project will be supplied by the subcontractor(s).

Travel: It is estimated that three (3) CURES staff will travel a total of 5 trips per year (averaging 200 miles round trip @ $0.56 per mile) which will include lodging ($90 a night) and meals ($56 for 3 meals). Travel costs is $4,000 for 2015/2016, $4,000 for 2017 and $2,300 in 2018.

Professional/Consultant Services: Allan Fulton (University of California, Davis) will assist CURES with grower identification and outreach and is budgeted $2,500 per year to pay for supplies and travel. MLJ-LLC will perform Task 3 (Study Design) through Task 7 (Summary Report) completing the sampling, analysis and report summaries. MLJ-LLC's budget includes personnel ($98,860), equipment/supplies ($8,603.50), transportation ($9,920) and analytical costs ($29,648) associated with sampling and conducting the field trials. MLJ-LLC will manage data collected as part of this study and work with the Project Team on developing the draft and final Summary Reports.

Other Expenses: No Other Expenses have been identified.

c. Other Funding Sources

As part of their commitment to the MPEP, four CV Coalitions have pledged funds for this project. Due to the timing of the proposal, the pledges are estimated but are expected to be a total of $80,000 over two years.

B-VIII. Budget Template (see attached excel spreadsheet)

B-IX. Appendices

Appendix 1: Project Leaders

Resume: Parry Klassen

Executive Director

East San Joaquin Water Quality Coalition

Coalition for Urban Rural Environmental Stewardship

Central Coast Groundwater Coalition

Parlier, CA

559-288-8125

pklassen@unwiredbb.com

Education

Bachelor of Science Degree in Agricultural Communications; emphasis in agronomy and journalism. California State University, Fresno, 1981.

Employment History

September 2004 to Present – Executive Director, East San Joaquin Water Quality Coalition. Manage the activities of this non-profit entity formed to assist members to be in compliance with the Irrigated Lands Regulatory Program. Responsibilities include managing relations with the Regional Water Board and coalition subcontractors and implementing outreach programs on improving water quality in the coalition region. www.esjcoalition.org

August 1999 to Present – Executive Director, Coalition for Urban/Rural Environmental Stewardship. Responsibilities include managing the non-profit organization and working with clients on a variety of research and communications projects. Research projects focus on evaluating management practices to protect surface and groundwater; outreach programs consist of developing publications, organizing meetings, presentation development and performance, media outreach and other communications functions. All projects are performed by forming alliances with various agricultural organizations to achieve the project goals. www.curesworks.org

January 2012 to Present – Executive Director, Central Coast Groundwater Coalition

Manage the activities of this non-profit entity created to fulfill the groundwater monitoring requirements of landowners and growers located in the Central Coast region of California. Responsibilities include managing subcontractors who perform well sampling and implementing the outreach program directed at 573 members who farm 204,000 acres in the region. www.centralcoastgc.org

1997 to 2004 -- Communications Consultant, Freelance Writer.

Worked on a variety of communications projects including media relations, issues management, and writing. Projects included copy writing and editing, organizing meetings, presentation development and performance, media outreach and other communications functions. Clients included Crop Life America, Almond Board of California, California Tree Fruit Agreement and other agricultural entities.

1995 – 1997 – Communications Manager, Western Plant Health Association – Manage communications activities for this trade association based in Sacramento.

1981 to 1995 -- Reporter and Editor

Reporter and editor for a number of agricultural publications, including *Farm Chemicals, California Farmer, Western Fruit Grower,* and *American Vegetable Grower* magazines. Also written extensively about greenhouse and ornamental crops, cotton, and related agricultural subjects.

Farming Background

1991 to present -- Own and operate fruit farm near Parlier.

1988 to 1990 -- Rented peach orchard in Ohio for direct market sales.

1979 to 1980 -- Worked during college on cotton and vegetable farm.

1970 to 1975 – Actively involved in family tree fruit farm in Reedley, CA. Growing, packing, and shipping operation included 150 acres of peaches, plums, nectarines, and vegetables. (Farm sold in 1975).

Resume: Allan Fulton

B-X. Allan E. Fulton - Irrigation and Water Resources Farm Advisor

University of California Cooperative Extension, Tehama, Glenn, Colusa, and Shasta Counties

Home Contact:	Employer Contact:
20810 Bare Road, Red Bluff, CA 96080	University of California Cooperative Extension
Home: (530) 527-1018	1754 Walnut Street, Red Bluff, CA 96080
Cell: (530) [illegible]	Office: (530) 527-2101

EDUCATION

Master of Science, Soil and Irrigation Science, Colorado State University, Fort Collins, CO, 1986

Bachelor of Science, Agronomy, Colorado State University, Fort Collins, CO, 1983

WORK EXPERIENCE

Irrigation and Water Resources Farm Advisor, Tehama, Glenn, Colusa, and Shasta Counties, University of California Cooperative Extension, Red Bluff, CA, 2000 – Present.

Develop, demonstrate, and extend irrigation and soil management practices for orchard and agronomic crops that sustain production, use water efficiently, and prevent off-site water quality impacts. Extend knowledge to water users in the northern Sacramento Valley concerning groundwater hydrology and integrated water management concepts. Educate water users of non-point source water quality regulations facing irrigated agriculture and the role of watershed management approaches to respond.

Managing Agronomist, den Dulk Farming Company, Kingsburg, CA 1997 – 2000. Co-managed 1100 acres of orchard and vine crops and 2400 acres of alfalfa and row crops near Hanford, California. Responsible to oversee management of irrigation, soil quality and plant nutrition, and pest management.

Soils, Water, and Winter Grains Farm Advisor, Kings County, University of California Cooperative Extension, Hanford, CA 1986 –1997. Develop, demonstrate, and teach irrigation management practices for orchard and agronomic crops that use water efficiently, reduce agricultural drainage and runoff. Investigate and provide information on soil and water amendments to manage soils with slow water infiltration resulting from irrigation water supplies of lower water quality. Evaluate salt tolerance of agronomic crops, trees, and halophytes. Study blending and cyclical approaches to re-use saline-sodic agricultural drainwater for irrigation. Research and extend knowledge on all agronomic aspects of irrigated wheat and barley production.

RECENT PROFESSIONAL ACTIVITY AND PUBLIC SERVICE

- Past President, California Chapter American Society of Agronomy, 2013/14
- Member of UC ANR Strategic Initiative Panel for Water, Dec. 1, 2011 - Nov. 30, 2013
- Technical editor for Tehama County AB-3030 Groundwater Management Plan Update. 2012
- Chair, Tehama County AB3030 Technical Advisory Committee. 2009
- Current member of the Glenn County Groundwater Technical Advisory Committee since 2001
- California Groundwater Resources Association, Affiliate. – "Groundwater Monitoring: Design, Analysis, Communication and Integration with Decision Making. Invited presenter, February 2009, Conference Speaker, Anaheim, CA

Recent Publications: Allan Fulton

Ayars, J. E., A. Fulton, and B. Taylor. Subsurface Drip Irrigation in California - Here to Stay? Agricultural Water Management Journal. January 2015. journal homepage: www.elsevier.com/locate/agwat.

O' Geen, Anthony, Thomas Harter, Helen Dahlke, Fogg, Graham, Samuel Sandoval, Allan Fulton, Saal, Matt, Paul Verdegaal, Rachael Elkins, Franz Niederholzer, Chuck Ingels, and David Doll. A Soil Survey Decision Support Tool for Groundwater Banking in Agricultural Landscapes. Submission for publication in California Agriculture. October, 2014. Pending peer review.

Fulton, A., J. Grant, R. Buchner, and J. Connell. Using the Pressure Chamber for Irrigation Management in Walnut, Almond and Prune. May 2014. UC ANR Publication 8503. http://anrcatalog.ucdavis.edu/Details.aspx?itemNo=8503.

Fulton, Allan. Technical Editor. Tehama County Flood Control and Water Conservation District Coordinated AB 3030 Groundwater Management Plan 2012. pp. 196. November 2012. http://www.tehamacountypublicworks.ca.gov/Flood/documents/2013_GWMP/1_GWMP_TOC.pdf.

Fulton, A. and the California Department of Water Resources, Northern District. Northern Sacramento Groundwater Newsletter Series (thirteen issues). April 2003 – June 2011.

http://cetehama.ucdavis.edu/Agriculture/Groundwater_Management.htm

Stewart, William, Allan Fulton, William Krueger, Bruce Lampinen, and Ken Shackel. A five-year study of Regulated Deficit Irrigation (RDI) in almond: Reducing consumption on a low water holding soil. California Agriculture. April-June 2011, Vol. 65 No.2 pp 90-95.

Fulton, Allan, Larry Schwankl, Kris Lynn, Bruce Lampinen, John Edstrom, and Terry Prichard. Using EM and VERIS technology to assess land suitability for orchard and vineyard development. Journal of Irrigation Science.DOI 10.1007/s00271-010-0253-1. December 2010.

Fulton, A., B. Sanden, and J. Edstrom. Soil Evaluation and Modification. Chapter 7. Prune Production Manual. Buchner, R. P., Editor. University of California, Agriculture and Natural Resources. In-Press. . July 17, 2010.

Fulton, A. and B. Sanden. Salinity Management. Chapter 6. Prune Production Manual. Buchner, R. P., Editor. University of California, Agriculture and Natural Resources. In Press. July 17, 2010.

Long, Rachael., Allan Fulton, and Blaine Hanson. Protecting Surface Water from Sediment-Associated Pesticides in Furrow-Irrigated Crops. Publication 8403. University of California, Agriculture and Natural Resources. March 2010. Pp. 16.

Long, Rachael F., Blaine R. Hanson, Allan E. Fulton, and Donald P. Weston. Mitigation techniques reduce sediment in runoff from furrow-irrigated cropland. California Agriculture. Division of Agriculture and Natural Resources. University of California. Vol. 64. No. 3. Pp. 135-140.

Buchner, R.P., Fulton, A., Gilles, C., Lampinen, B., Shackel, K., Metcalf, S., Little, C., Pritchard, T. and Schwankl, L. "Effects of Regulated Deficit Irrigation on Walnut (Juglans regia) Grafted on Northern California Black (Juglans hindsii) or Paradox Rootstock." Proceedings 5th International Symposium on Irrigation of Horticultural Crops. Mildura, Australia. January 2007.

Lubell, M. and A. Fulton. Local Policy Networks and Agricultural Watershed Management. Journal of Public Administration Research and Theory. Advance Access published November 4, 2007.

Current Projects, Time Commitments and Impacts on Proposed Project – Allan Fulton

Project Title or Creative Activity/ Duration	Role (PI, Co-PI, etc.)	Collaborators (with affiliation)	Support Source
Almond Water Production Function Research	Provide oversight of Tehama County field experiment. Work routinely with grower cooperator. Impose irrigation treatments, oversee field assistant and collection of water, crop development, and yield data. Involved in data analysis and reporting to Almond Board of California.	Ken Shackel, Professor, Plant Sciences, UCD, David Doll, UCCE Farm Advisor, Merced County, Blake Sanden, UCCE Farm Advisor, Kern County, and Bruce Lampinen, UCCE Statewide Extension Specialist	Almond Board of California
Evaluating Physiological Indicators of Early Season Water Stress in Walnut	Provide oversight of Tehama County field experiment. Work routinely with grower cooperator. Impose irrigation treatments, oversee field assistant and collection of water, crop development, and yield data. Involved in data analysis and reporting to Walnut Research Board.	Ken Shackel, Professor, Plant Sciences, UCD and Bruce Lampinen, UCCE Statewide Extension Specialist	California Walnut Research Board
Evaluation of water use and crop coefficients in mature walnuts.	Co-PI. Arranged two orchards to conduct experiment, routinely maintain instrumentation and collect field data. Involved with data analysis and extension of results.	Richard Snyder, Co-PI, UCCE Specialist, Cayle Little, Co-PI California Department of Water Resources, and Richard Buchner, Farm Advisor, UCCE, Tehama County	California Department of Water Resources and Tehama County
Evaluation of water use and crop coefficients in French Prune.	Co-PI, Arranged one orchard to conduct experiment, routinely maintain instrumentation and collect field data. Involved with data analysis and extension of results	Richard Snyder, Co-PI, UCCE Specialist, Cayle Little, Co-PI California Department of Water Resources, and Richard Buchner, Farm Advisor, UCCE, Tehama County	California Department of Water Resources and Tehama County

Project Title or Creative Activity/ Duration	Role (PI, Co-PI, etc.)	Collaborators (with affiliation)	Support Source
UC-ANR Web-based Irrigation Scheduling and Nitrogen Management Tool for California Crops	Leader in the development of modules and algorithms that expand UC ANR's Crop Manage web-based irrigation scheduling to almond and walnut orchard crops.	Michael Cahn, UCCE Monterey County, and Khalid Bali, UCCE, Imperial County.	California Department of Water Resources
Nitrogen Management Training for California Certified Crop Advisors (CCA's)	Served on a UC ANR Steering Committee chaired by Water Strategic Initiative Leader, Doug Parker. Committee developed curriculum for a 1 1/2 day training and certification session on nitrogen management in irrigated agriculture. I co-authored and presented curriculum related to irrigation management and its interaction with nitrogen managment and I contributed to the development of an interactive training exercise on nitrogen management decision making.	Doug Parker, UC ANR Water Strategic Initiative Leader, Patrick Brown, Professor Plant Sciences, Tim Hartz, UCCE Statwide Vegetable Crops Specialist, Stuart Pettygrove, UCCE Emeritus, Larry Schwankl, UCCE Emeritus, Dan Munk, UCCE Farm Advisor, Fresno County, and others.	California Department of Food and Agriculture

Resume: Michael L. Johnson, LLC

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Education – Dr. Michael L. Johnson

Ph.D. 1984, University of Kansas
M.A. 1977, University of Colorado
B.A. 1974, University of Colorado

Past Positions

Research Scientist, Center for Watershed Sciences, John Muir Institute of the Environment, 2008 – 2010
Adjunct Associate Professor, Department of Medicine and Epidemiology, School of Veterinary Medicine, 2004 - 2010
Associate Research Scientist, John Muir Institute of the Environment, 1998 – 2008
Director, Lead Campus Program in Ecotoxicology, UC Toxic Substances Research & Teaching Program 2000-2005
Associate Researcher, Department of Civil and Environmental Engineering, 1992 - 1998
Lecturer, Department of Environmental Toxicology, 1998-99
Lecturer, Department of Wildlife, Fish, and Conservation Biology, UC Davis, 1993 - 1995
Assistant Scientist, Kansas Biological Survey, 1991-1992
Adjunct Assistant Professor, Department of Systematics and Ecology, University of Kansas, 1989-1992
Research Associate, Kansas Biological Survey, 1988-1991
Postdoctoral Research Associate, Department of Systematics and Ecology, University of Kansas, 1987-1988
Lecturer, Department of Mathematics, University of Kansas, 1984-1987

Related Project /Experience

Study Title: Establishing cost efficient methods to measure nitrate movement beyond the root zone when using nutrient BMPs in California Specialty Crops

Project Abstract: This project was funded by a Specialty Crop Grant by the California Department of Food and Agriculture (CDFA) and was awarded to the Coalition of Urban and Rural Environmental Stewardship (CURES). Michael L. Johnson, LLC (MLJ-LLC) was a subcontractor to the project and implemented the monitoring design, data review and storage, data analysis and results write up. The project's main goal was to establish a reliable and repeatable scientific method to characterize the movement of nitrogen fertilizers beyond the plant root zone. After a literature review, the project focused on evaluating the ability of using an Automated Monitoring System (UMS) versus a traditional suction lysimeters system to collect water samples in cauliflower, lettuce and walnut fields below the root zone. Both methods were able to effectively collect water and nitrate concentrations varied across the fields and at different depths. Due to the lower expense of lysimeters, they were used in a field trial in two lettuce fields to evaluate the amount of nitrogen leaching past the root zone. One of the adjacent lettuce fields received the normal amount of nitrogen and the other received half that amount. The results of the study were affected by significant differences in permeability between the two fields. However, the results of the two year study on both methodology and management practice effectiveness have found that using a lysimeter system to characterize movement of nitrogen fertilizers past the root zone is both cost effective and reliable. The protocols used within the field trial on lettuce are being further refined based on the study results and will assist growers in both the Central Valley and Central Coast better understand the amount of nitrogen leaching past the root zone for specific crops.

Project Methods:

Samples were collected in 2014 to optimize the depths of sampling in the vegetable crops and develop a process for determining the number of instruments that are needed to adequately sample water moving past the root zone at a larger scale (part or all of a planting block depending on size). Sampling occurred in 2014 after initial storm events within Stockton, Salinas and Gonzales locations and continued during additional winter storms and irrigation events in 2014. To better understand variability in soil characteristics that can affect moisture content and water movement, hydraulic conductivity and/or soil texture analysis of soil samples were also conducted in 2014. The results from the additional winter sampling and analysis were then used to develop a field trial on lettuce utilizing lysimeters to measure the difference in nitrogen concentration in fields with different nitrogen management practices. The field trial found that the amount of nitrate present in the soil prior to planting did not differ between the two fields and therefore any differences in nitrate concentrations measured in the water moving past the root zone were due to the amount of nitrate applied during the crop cycle. However, the permeability between the two fields was found to be significantly different; one field had twice the hydraulic conductivity as the other. The field with the higher hydraulic conductivity received the lower amount of nitrate. The nitrate concentrations in the water samples collected below the root zone were twice as high in the field with the highest hydraulic conductivity even though half as much nitrate was applied. There were no differences in moisture content, crude protein, or total N content of the trimmed tissue or the Romaine heads between the two sides.

<u>Grants and Contracts</u>

University of California (All grants as Principle Investigator unless noted otherwise)

Identifying pharmaceuticals in the Sacramento River. State Water Resources Control Board June 2007 – March 2011 ($20,037)

Review of ammonia in the Delta. State Water Resources Control Board June 2008 – March 2010 ($40,697)

Identifying pharmaceuticals in the Napa River and tributaries. Napa Sanitation District November 2008 – June 2010 ($75,000)

Pelagic Organism Decline. State Water Resources Control Board June 2008 – March 2010 ($450,000)

QAPP development for permitting operations. California Urban Water Agency July 2008 – September 2008 ($8,835)

Identifying pharmaceuticals in Sonoma Creek and tributaries. Sonoma County Water Agency April 2007 – June 2009 ($75,000)

Regional Data Center – California Environmental Data Exchange Network. State Water Resources Control Board May 2007 – present ($299,500)

Evaluation of the toxicity of biodiesel fuels. California Air Resources Board June 2007 – June 2009 ($185,000)

Effect of Light Brown Apple Moth pheromones on honey bees. California Department of Food and Agriculture December 2007 – December 2009 ($187,425)

Guidance Document and Recommendations on the Types of Scientific Information to be Submitted by Applicants for California Fuels Environmental Multimedia Evaluations. California Air Resources Board. June 2007 – May 2009 ($55,110)

Phase II Continuation of Monitoring of Agricultural Drainage Water Quality in the Central Valley of California. CAL EPA Water Control Board. December 2003 – June 2008 ($2,337,837)

City of Ukiah Healthy Waterways Study. City of Ukiah. July 2006 – December 2008 ($35,000)

Review & Assessment of Apalachee I BMPs and Monitoring Needs, Task 2. El Dorado County. November 2004 - January 2009 ($17,472)

Review & Assessment of Apalachee I BMPs and Monitoring Needs, Task 3. El Dorado County. November 2004 – January 2005 ($17, 472)

Identification of Bacterial Sources for the East San Joaquin Water Quality Coalition. East San Joaquin Water Quality Coalition. July 2006 – December 2006 ($7,123)

Bacterial Source Identification Analysis. East San Joaquin Water Quality Coalition. April 2007 – June 2008 ($16,673)

Identification of Bacterial Sources for the Sacramento Valley Water Quality Coalition. July 2006 – December 2007 ($6,600)

Lake County Healthy Waterways Study. Lake County. August 2005 – February 2008 ($34,500)

Detection of Fecal Contaminants in Groundwater. Lake County. March 2007 – December 2008 ($6,840)

Scientific Peer Review of Public Health Goal Documents. CAL EPA – Office of Environmental Health Hazard Assessment. July 2005 – August 2005 ($3,000)

Feather River PRISM. Coalition for Urban/Rural Environmental Stewardship. January 2005 – January 2008 ($70,000)

Feather River Prop 50 Monitoring and Modeling. California State Water Resources Board November 2005 – December 2007 ($143,331)

Identification of Bacterial Sources for the San Joaquin County & Delta Water Quality Coalition. San Joaquin County and Delta Water Quality Coalition. July 2006 - December 2006 ($7,300)

Tahoe Basin Toxicity Testing. California Department of Transportation October 2005 – May 2008 ($6,281)

Total Maximum Daily Load Monitoring. State Water Resources Control Board March 2007 – February 2008 ($139,500)

Central Valley Bioassessment 2005-06. Central Valley Regional Water Quality Control Board, December 2005 – December 2006 ($276,048)

El Dorado County Department of Transportation Sampling and Analysis of Water Runoff. Eldorado County Department of Transportation February 2004 – February 2008. ($475,000)

Using a sensitive Japanese Medaka (Oryzias latipes) fish model for the detection of endocrine disruptors in ground water. State Water Resources Control Board, June 2004 – May 2006 ($238,000) (Co-PI, S. Teh PI)

Central Valley Bioassessment 2004-05. Central Valley Regional Water Quality Control Board, April 2004 – June 2005 ($228,000)

Using a sensitive Japanese Medaka (Oryzias latipes) fish model for endocrine disruptors screening. U.S. Environmental Protection Agency, October 2003 – September 2006 ($399,167) (Co-PI, S. Teh PI)

Fire and fuels management, landscape dynamics, and fish and wildlife resources: study design for integrated research on the Plumas and Lassen National Forests -- Small mammal distribution, abundance, and habitat relations. USDA-Forest Service, 2002-2007. ($1,604,000); (Co-PI, D. Kelt PI)

TMDL monitoring of Central Valley Watersheds 2002-03. Central Valley Regional Quality Control Board, December 2002 – August 2003 ($340,147)

Review of Angora Meadows Monitoring Data. El Dorado County, March – May 2003 ($2,061)

Ecotoxicology Lead Campus Program. UC Toxic Substances Research and Teaching Program, June 2000 – June 2004 ($1,266,594)

Central Valley Bioassessment 2003-04. Central Valley Regional Water Quality Control Board, June 2003 – June 2004 ($186,620)

Review of Public Health Goals Draft Documents for 1,1,2,2-Tetrachloroethane, Chlorobenzene, Simizine, and 1,1-Dichloroethane. Office of Environmental Health Hazard Assessment, Cal EPA, December 1998 – January 2003. ($6,000)

Review of SFBRWQCB Risk Based Screening Levels for Ecological Receptors. UC Berkeley, April 2003 – June 2003 ($2,000)

Water quality modeling for the Shasta River dissolved oxygen and temperature TMDLs. North Coast Regional Water Quality Control Board, December 2003 – December 2004, ($115,000) Co-PI, (J. Quinn, PI)

TMDL monitoring of Central Valley Watersheds 2003-04. Central Valley Regional Water Quality Control Board, November 2003 – March 2004, ($259,973)

Statewide toxicity testing research project. California Department of Transportation. June 2000 – June 2003 ($1,710,000)

Simplex modeling of an urban watershed. Vallejo Sanitation and Flood Control District. August 2000 – August 2001 ($29,000)

Perchlorate exposure in drinking water. California Department of Health Services. (Co-PI, G. Fogg, P.I.) June 1999 – September 2001 ($222,603)

FREP project. California Department of Food and Agriculture, February 2000 – March 2000 ($4,000)

Estrogenicity of selected herbicides and adjuvants. California Department of Transportation. October 1998 – June 2002 ($241,627)

Simplex modeling of an urban watershed. Fairfield-Suisun Sewer District. December 2000 – December 2001 ($10,000)

MTBE analysis in California. University of California Toxic Substances Research and Teaching Program (Co-PI). January 1998 - October 1998 ($220,000)

TMDL analysis of North Coast watersheds (North Coast River Loading Study). California Department of Transportation, July 1997-June 2002 ($1,541,173)

The impact of stormwater runoff on North Coast rivers (Small Stream Crossing Study). California Department of Transportation, November 1997-June 2002 ($1,820,144)

San Pablo Bay National Wildlife Refuge vegetation monitoring plan. California Department of Transportation, July 1997-June 2002 ($419,250)

Small mammal survey of the Alhambra Creek Wetlands. California Department of Transportation, September 1997-October 1997 ($12,000)

Baseline vegetation survey of the East San Pablo Bay Unit of the San Pablo Bay National Wildlife Refuge. California Department of Transportation, July 1996-March 1997 ($50,000)

An integrated assessment of a linked wetland-nearshore estuarine ecosystem at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1996-June 1997 ($363,000)

An integrated assessment of a linked wetland-nearshore estuarine ecosystem at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1995-June 1996 ($160,000)

An integrated approach to assessing water management options in a major watershed: Extending a hydrodynamic-water quality model to include biological and politico-economic components (Co-PI). U.S. Environmental Protection Agency (EPA-NSF), October 1996-September 1999 ($1,292,627)

Development of an ecological risk assessment model. Year 2. California Environmental Protection Agency, July 1995 - June 1996 ($40,000)

Salt marsh hydrology and mitigation of flooding. California Department of Transportation, October 1995 - June 1996 ($50,000)

Salt marsh modeling. National Biological Survey, November 1994 - October 1995 ($59,325)

UC Davis Environmental Education Partnership (UCDEEP). (Co-PI) Department of Defense, October 1994 - September 1995 ($1,660,207)

An integrated ecological assessment of three wetlands sites at Mare Island Naval Shipyard. University of California Toxic Substances Research and Teaching Program, July 1994 - June 1996 ($79,453)

Development of an ecological risk assessment model and symposia. California Environmental Protection Agency, July 1994 - June 1995 ($250,000)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management: Data management and data analysis (Year 2). Subcontract to University of Kansas, June 1993 - June 1994 ($23,000)

Hydrodynamic modeling of Pt. Mugu Lagoon. U.S. Fish and Wildlife Service, August 1993 - December 1993 ($5,000)

Feasibility study of alternate wetland restoration plans for the Napa Marsh Unit of the San Pablo Bay National Wildlife Refuge. U.S. Fish and Wildlife Service, January 1993 - December 1994 ($85,286)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management. Phase I. Selection of watersheds. U.S. EPA, Region IX, August 1992 - June 1993 ($29,000)

An assessment of the effects of nonpoint source pollution on the biotic integrity of Walnut Creek, and the role of riparian vegetation in mitigating nonpoint source pollution: Data management and data analysis. Subcontract to University of Kansas, October 1992 - September 1995 ($35,443)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management: Data management and data analysis (Year 1). Subcontract from the University of Kansas, June 1992 - June 1993 ($23,000)

University of Kansas

Data for validation of EPA modeling. U.S. EPA - ERL Duluth, August 1990 - March 1991 ($7500)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management (Year 1). U.S. EPA, June 1991 - June 1992 ($1,250,000)

A regionalized assessment of the influences of rural nonpoint source pollution on the ecological integrity of stream ecosystems and evaluation of associated pollution control management (Year 2). U.S. EPA, June 1992 - June 1993 ($1,450,000)

An assessment of the effects of nonpoint source pollution on the biotic integrity of Walnut Creek, and the role of riparian vegetation in mitigating nonpoint source pollution. U.S. EPA, August 1992 - July 1995 ($325,000)

PUBLICATIONS

Gaines, M. S. and **M. L. Johnson**. 1982. Home range size and population dynamics in the prairie vole, *Microtus ochrogaster*. *Oikos* 39:63-70.

Abdellatif, E., K. B. Armitage, M. S. Gaines, and **M. L. Johnson**. 1982. The effect of watering on a prairie vole population. *Acta Theriologica* 27:243-255.

Gaines, M. S. and **M. L. Johnson.** 1984. A multivariate study of the relationship between dispersal and demography in populations of *Microtus ochrogaster* in eastern Kansas. *American Midland Naturalist* 111:223-233.

Johnson, M. L. and M. S. Gaines. 1985. The selective basis for emigration of the prairie vole *Microtus ochrogaster*: Open field experiment. *Journal of Animal Ecology* 54:399-410.

Gaines, M. S., C. L. Fugate, **M. L. Johnson**, D. C. Johnson, J. R. Hisey, and D. Quadagno. 1985. Manipulation of aggressive behavior in male prairie voles (*Microtus ochrogaster*) implanted with testosterone in silastic tubing. *Canadian Journal of Zoology* 63:2525-2528.

Danielson, B. J., **M. L. Johnson**, and M. S. Gaines. 1986. An analysis of a method for comparing residents and colonists in a natural population of *Microtus ochrogaster*. *Journal of Mammalogy* 67:733-736.

Johnson, M. L. and M. S. Gaines. 1987. The selective basis for dispersal of the prairie vole, *Microtus ochrogaster*. *Ecology* 68:684-694.

Gaines, M. S. and **M. L. Johnson**. 1987. Phenotypic and genotypic mechanisms for dispersal in *Microtus* populations and the role of dispersal in population regulation. In, B. D. Chepko-Sade and Z. Halpin (eds.). Mammalian Dispersal Patterns: The Effect of Social Structure on Population Genetics. The University of Chicago Press, Chicago, IL.

Boonstra, R., C. J. Krebs, M. S. Gaines, **M. L. Johnson**, and I. M. T. Craine. 1987. Natal philopatry and breeding systems in *Microtus*. *Journal of Animal Ecology* 56:655-673.

Johnson, M. L. and M. S. Gaines. 1988. Demography of the western harvest mouse, *Reithrodontomys megalotis*, in eastern Kansas. *Oecologia* 75:405-411.

Johnson, M. L. 1989. Exploratory behavior and dispersal: a graphical model. Canadian *Journal of Zoology* 67:2325-2328.

Hedrick, P. W., M. S. Gaines, and **M. L. Johnson**. 1989. Owl feeding habits on small mammals. *Occasional Papers of the Museum of Natural History* 133:1-7.

Gaines, M. S., E. M. Abdellatif, **M. L. Johnson**, and K. B. Armitage. 1990. The effect of aggression on dispersal and related demographic parameters in *Microtus ochrogaster* populations in Eastern Kansas. In, R. H. Tamarin, R. S. Ostfeld, S. R. Pugh, and G. Bujalska, (eds.). Social Systems and Population Cycles in Voles. Birkhauser Verlag, Basel

Johnson, M. L. and M. S. Gaines. 1990. Evolution of dispersal: theoretical models and tests using birds and mammals. *Annual Review of Ecology and Systematics* 21:449-480.

Gaines, M. S., N. C. Stenseth, **M. L. Johnson**, R. A. Ims, and S. Bondrup-Nielson. 1991. A response to solving the enigma of population cycles with a multifactorial prespective. *Journal of Mammalogy* 72:627-631.

Johnson, M. L., D. G. Huggins, and F. deNoyelles. 1991. Ecosystem modeling with LISREL: A new approach for measuring direct and indirect effects. *Ecological Applications* 1:383-398.

Gaines, M. S., G. R. Robinson, R. D. Holt, **M. L. Johnson**, and J. E. Diffendorfer. 1992. The effects of habitat fragmentation on small mammal populations. In, D. R. McCullough and R. H. Barrett (eds.). Wildlife 2001: Populations. Elsevier Science Publishers, Ltd., London.

Robinson, G. R., R. D. Holt, M. S. Gaines, S. P. Hamburg, **M. L. Johnson**, H. S. Fitch, and E. A. Martinko. 1992. Diverse and contrasting effects of habitat fragmentation. *Science* 257:524-526.

Huggins, D. G. and **M. L. Johnson**. 1992. Ecological consequences of the control and elimination of macrophytes in small ponds by atrazine and grass carp. In, Proceedings from the Regional Lake Management Conference, North American Lake Management Society. June 1991.

Johnson, M. L., D. G. Huggins, and F. deNoyelles, Jr. 1993. Structural equation modeling and ecosystem analysis. In, R. L. Graney, J. H. Kennedy, and J. H. Rodgers, Jr. (eds.). Aquatic Mesocosm Studies in Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Huggins, D. G., **M. L. Johnson**, and F. deNoyelles, Jr. 1993. The effect of atrazine on aquatic ecosystems: An assessment of direct and indirect effects using structural equation modeling. In, R. L. Graney, J. H. Kennedy, and J. H. Rodgers, Jr. (eds.). Aquatic Mesocosm Studies In Ecological Risk Assessment. Lewis Publishers, Boca Raton, FL.

Johnson, M. L., L. Holmes, A. Salveson, M. S. Denison, and D. M. Fry. 1998. Environmental estrogens in agricultural drain water from the Central Valley of California. Bulletin of Environmental Contamination and Toxicology 60:609-614.

Venkatram, A., L. Burns, C. Chen, J. Irwin, and **M. Johnson**. 1998. Model testing and validation. In, K. H. Reinert, S. M. Bartell, G. R. Biddinger (eds.). Ecological Risk Assessment Decision-Support System: A Conceptual Design. Proceedings from SETAC Ecological Risk Assessment Modeling Workshop; 1994 Aug 23-28; Pellston MI. Pensacola FL: Society of Environmental Toxicology and Chemistry. 120 p.

Pagel, J. E., D. A. Bell, and **M. L. Johnson**. 1998. When is an endangered species recovery complete: Is de-listing the American Peregrine Falcon appropriate? Proceedings of the 63rd Transactions of the North American Wildlife Conference.

Hansen, L. J. and **M. L. Johnson**. 1999. Conservation and Toxicology: Integrating the disciplines. *Conservation Biology* 13:1225-1227.

Hansen, L. J. and **M. L. Johnson**. 1999. Conservation and Toxicology: The need to integrate the disciplines. *Environmental Toxicology and Chemistry* 18:2121-2122.

Scow, K. M., G. E. Fogg, D. E. Hinton, and **M. L. Johnson**, eds. 2000. Integrated Assessment of Ecosystem Health. Lewis Publishers, Boca Raton, FL. (Book Editor)

Mayfield, R. L., D. Van Vuren, and **M. L. Johnson**. 2000. Demography of an insular endemic rodent, Peromyscus maniculatus santacruzae, on Santa Cruz Island. *Southwestern Naturalist* 45:508-513.

Van Vuren, D., **M. L. Johnson**, and L. Bowen. 2001. Impacts of feral livestock on island watersheds. *Pacific Science* 55:285-289.

Torres, K. C. and **M. L. Johnson**. 2001. Bioaccumulation of metals in plants, arthropods, and house mice in a seasonal wetland. *Environmental Toxicology and Chemistry* 20:2617-2626.

Torres, K. C. and **M. L. Johnson**. 2001. Testing of metal bioaccumulation models with measured body burdens in mice. *Environmental Toxicology and Chemistry* 20:2627-2638.

Grigione, M. M. and **M. L. Johnson**. 2002. The effects of roads on carnivores. A case study of mountain lions (*Felis concolor*) in California. Managing for Healthy Ecosystems. CRC Press LLC, Boca Raton FL.

Sarakinos, H. C., **M. L. Johnson**, and M. J. Vander Zanden. 2002. A synthesis of tissue-preservation effects on carbon and nitrogen stable isotope signatures. *Canadian Journal of Zoology* 80:381-387.

Bowen, L., B. M. Aldridge, F. Gulland, J. Woo, W. Van Bonn, R. DeLong, J. L. Stott, and **M. L. Johnson.** 2002. Molecular characterization of expressed *DQA* and *DQB* genes in the California sea lion (*Zalophus californianus*). *Immunogenetics* 54:332-347.

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Appendix II: Cooperators

Appendix III: Supporters